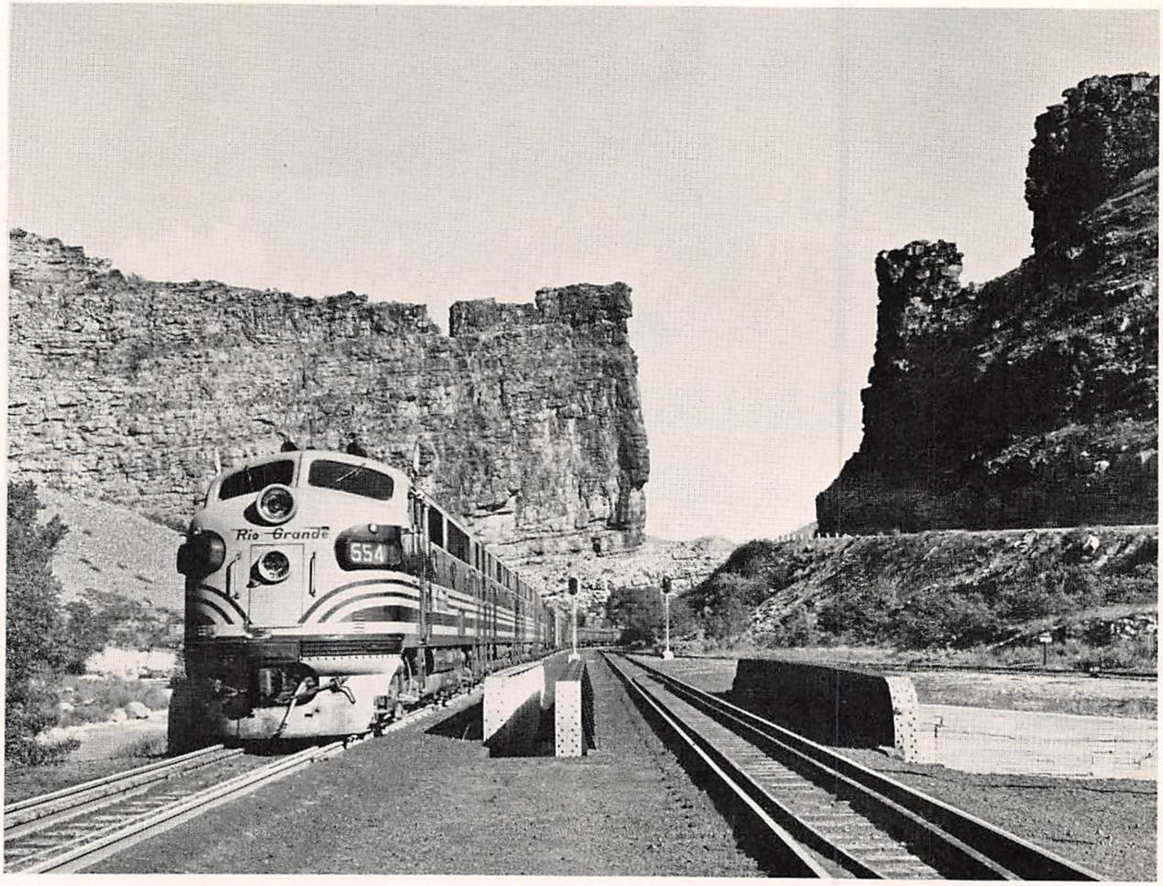
RAILWAY SIGNAL SYSTEMS

GENERAL RAILWAY SIGNAL COMPANY

PAMPHLET 750

G·R·S
RAILWAY SIGNAL
SYSTEMS



G-R-S automatic block signals on the Denver and Rio Grande Western.

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G·R·S
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PAMPHLET 750

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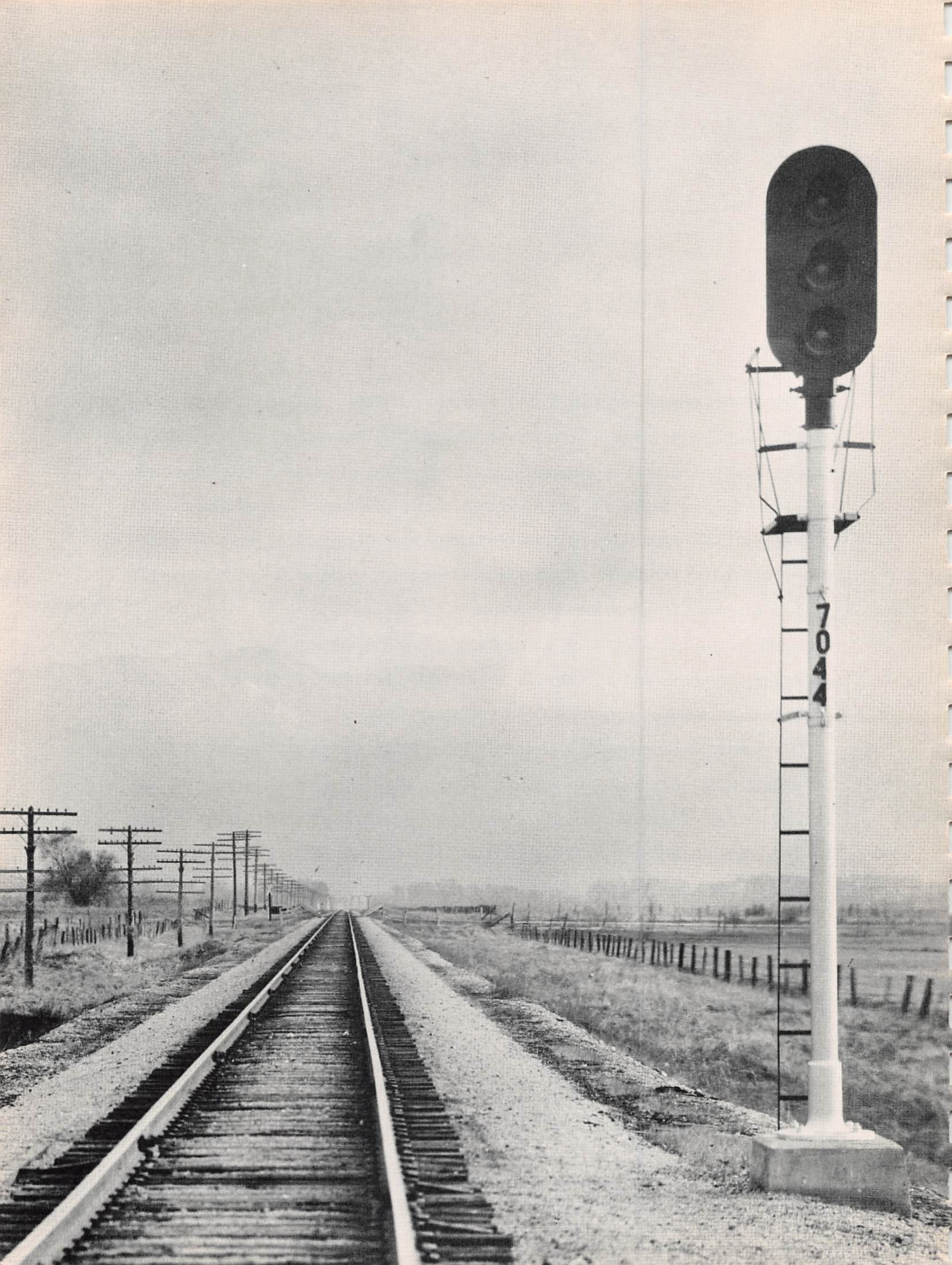
INTRODUCTION

The first railroad signaling had a single purpose - to keep trains from running into each other. Modern signaling still has safety as its fundamental purpose, but, in the very methods used to secure and improve safety, we have found means to make train operation faster and more efficient. Today, railroads are installing new signaling or modernizing older signaling as much for the direct economic benefits to be gained as for improved safety of operation.

This economic approach to railway signaling has brought forth new signaling systems and appliances specifically designed to facilitate train operation as well as to guarantee maximum safety.

This pamphlet contains brief descriptions of the principal G-R-S signaling systems. Most of these systems are described in more detail in separate G-R-S publications. For more specific information, ask your G-R-S representative. Addresses are listed on page 205.

For descriptions of G-R-S signaling appliances, ask for Pamphlet 751.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CLOSED TRACK CIRCUIT

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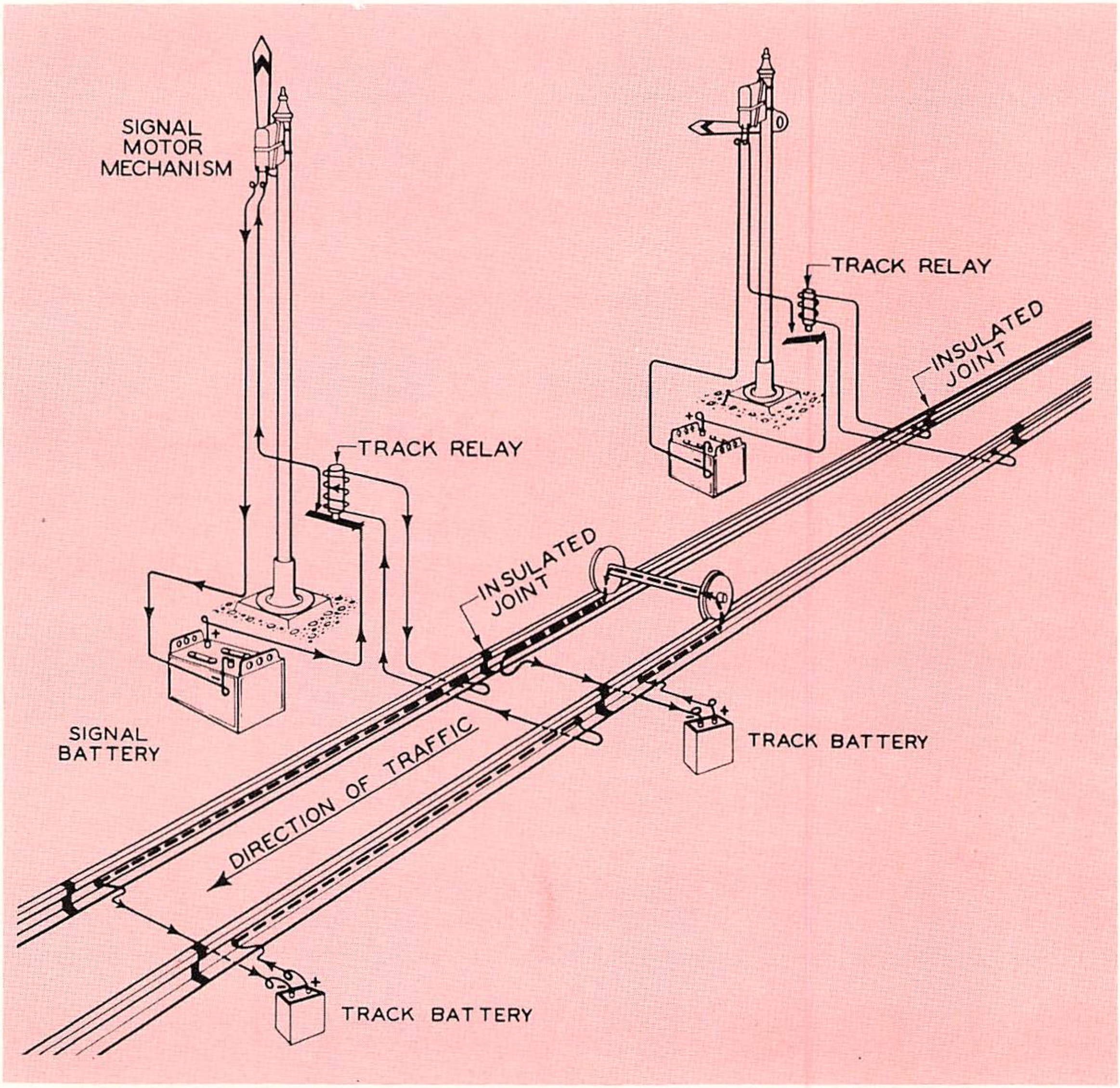
SIGNAL
MOTOR
MECHANISM
TRACK RELAY
TRACK RELAY
INSULATED JOINT
INSULATED JOINT
SIGNAL BATTERY
TRACK BATTERY
DIRECTION OF TRAFFIC
TRACK BATTERY

Figure 1. Simplified diagram of closed circuit d-c. track circuit.

INTRODUCTION

All modern signaling systems - block, interlocking, traffic control, speed control, etc. - are based on the use of the closed track circuit.

The description which follows deals with the fundamentals of several of the more common track circuits. Before ordering equipment to install track circuits, you should consult with your G-R-S representative so he can recommend the most efficient arrangement to fit your requirements.

ELEMENTARY PRINCIPLES OF OPERATION

Figure 1 shows a simplified diagram of two such track circuits, arranged in succession as they would be in a very elementary block system.

The track is divided into electrically isolated sections by insulated rail joints. A battery is connected to the rails at one end of the track circuit, and a relay is connected to the rails at the other end.

As shown by the track circuit in the foreground in Figure 1, when there is no train on the track circuit, current flows from the battery up one rail, through the relay coils, and back to the battery through the other rail. Thus the relay is energized, its front contact* is closed, and energy from the signal battery feeds through the front contact of the track relay to the signal, keeping the signal in its clear position.

When a train enters upon such a track circuit, as shown by the track circuit, in the background of Figure 1, most of the current from the track battery flows through the steel wheels and axles of the train, as this is a path of much lower resistance than the multiple path through the coils of the track relay. With not enough current flowing through the track relay to keep its armature up, it opens its front contact, thus opening the signal battery feed to the signal, and the signal assumes its most restrictive position.

---

*Front contact and back contact are terms commonly used in railway signaling to describe relay contacts. A front contact is closed when the relay is energized; a back contact is closed when relay is deenergized.

The resistors connected in the battery leads to the track, limit the discharge current from the batteries.

This is a fail-safe circuit. If a rail breaks, if a battery is exhausted, or if battery or relay leads from the rails are broken or crossed, the associated signal will show its most restrictive aspect.

Figure 1 is, of course, a very elementary diagram. An actual track circuit nearly always includes many lengths of rail. To insure good transmission of the track battery current to the track relay, these rails are bonded together, as the connections afforded by the joint bars cannot be relied upon to furnish a low resistance path. Naturally, track circuits cannot be operated with metallic ties. There is, even with wooden ties, some leakage of the track battery current through the ties and ballast. The amount of this leakage will vary with the nature of the ballast, the weather conditions (wet or dry), voltage of the track battery, and temperature. Another factor to be considered is the resistance of the rails themselves. This will vary with the weight of the rail and with the type and condition of the rail bonding. Temperature will also, to a certain degree, affect both the rail resistance and the relay resistance.

From the foregoing you will see that it is impossible to state accurately how long a given track circuit may be without knowing the nature of the factors mentioned: ballast, bonding, rail weight, drainage and temperature conditions, type and condition of track battery, etc. Please note that estimated lengths for track circuits in the following sections are based on a gage of 4 feet 8-1/2 inches. Variations from this gage will affect ballast resistance and, in turn, maximum permissible lengths of track circuits.

D-C. TRACK CIRCUITS

Ordinarily, d-c. neutral track circuits, such as shown in Figure 1, with good ballast conditions and bonding may be from 4000 feet to 6000 feet long.

Any of various kinds of batteries may be used to energize the track circuit. Present practice is to use primary cells or lead-acid or nickel-iron storage cells. Usually sufficient track voltage can be obtained from one lead-acid or nickel-iron storage cell or two primary battery cells. If large reserve capacity is desired, primary cells are connected in multiple.

If a dependable supply of a.c. is available, d-c. track circuits may be fed from the a.c. through a suitable rectifier.

A-C. TRACK CIRCUITS FOR STEAM ROADS

A-c. track circuits operate on the same basic principle as d-c. track circuits, except, of course, that a.c. instead of d.c. is fed to the rails, and the relay is usually an a-c. device.

Figure 2 shows a simple a-c. track circuit with a single-element track relay, a relay which receives all of its energy from the rail circuit.

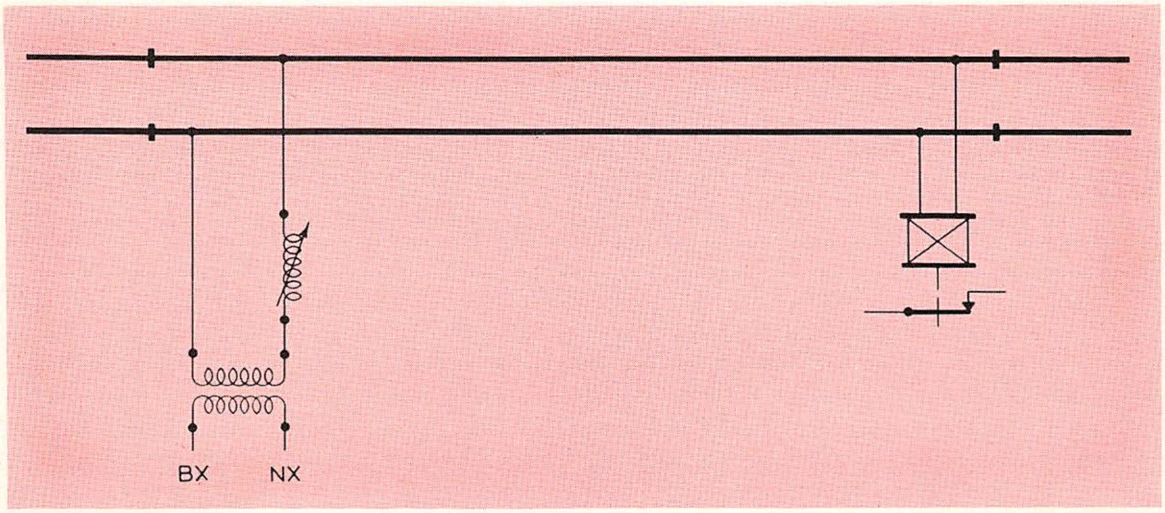

Figure 2. Single-element relay a-c. track circuit for steam roads.

Inasmuch as the single-element a-c. track relay is a relatively inefficient device, such track circuits are limited in length to a maximum of about 1000 feet.

Figure 3 shows an a-c. track circuit with a two element a-c. track relay. Two-element track relays are so called because they have two windings, a local winding and a track winding. Both these windings must be properly energized to cause the relay to close its front contacts.

The local winding is connected to the transmission line. It furnishes the major part of the energy to operate the relay. The track winding, sometimes called the control winding, is connected to the rails. Relatively small changes in the track energy level can thus control the relay.

Where the minimum ballast resistance is not less than 4 ohms per 1000 feet of track, maximum length for a 50- or 60-cycle track circuit using a two-element relay should not exceed 8000 feet. Where minimum ballast resistance is as low as 2 ohms per 1000 feet, maximum length should not exceed 5500 feet. Where 100-cycle energy is used, these maximum lengths should be reduced to 6000 and 5000 feet respectively.

In Figure 3, an adjustable reactor, instead of a resistor, is shown for

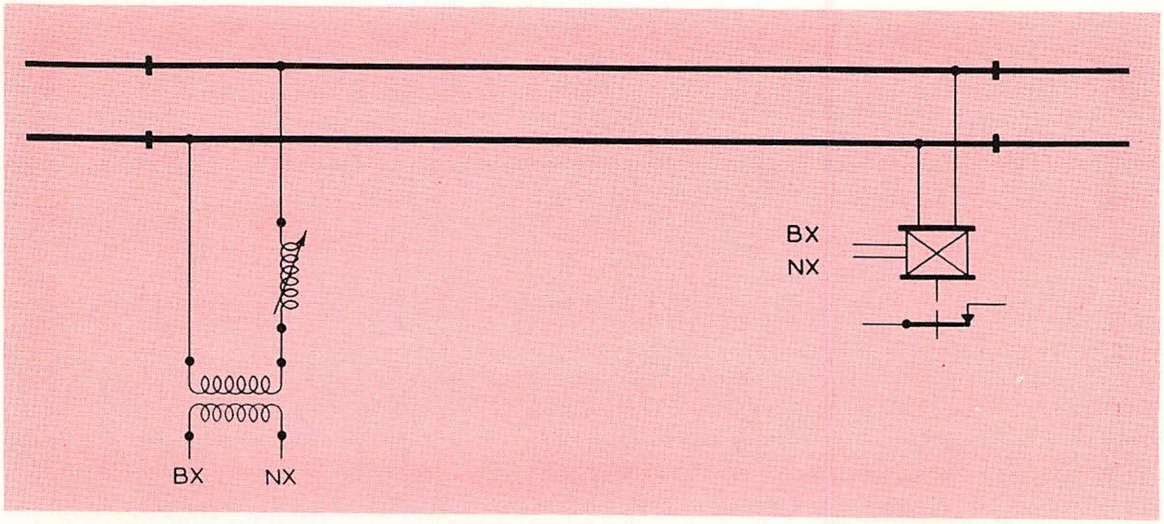

Figure 3. Two-element relay a-c. track circuit for steam roads.

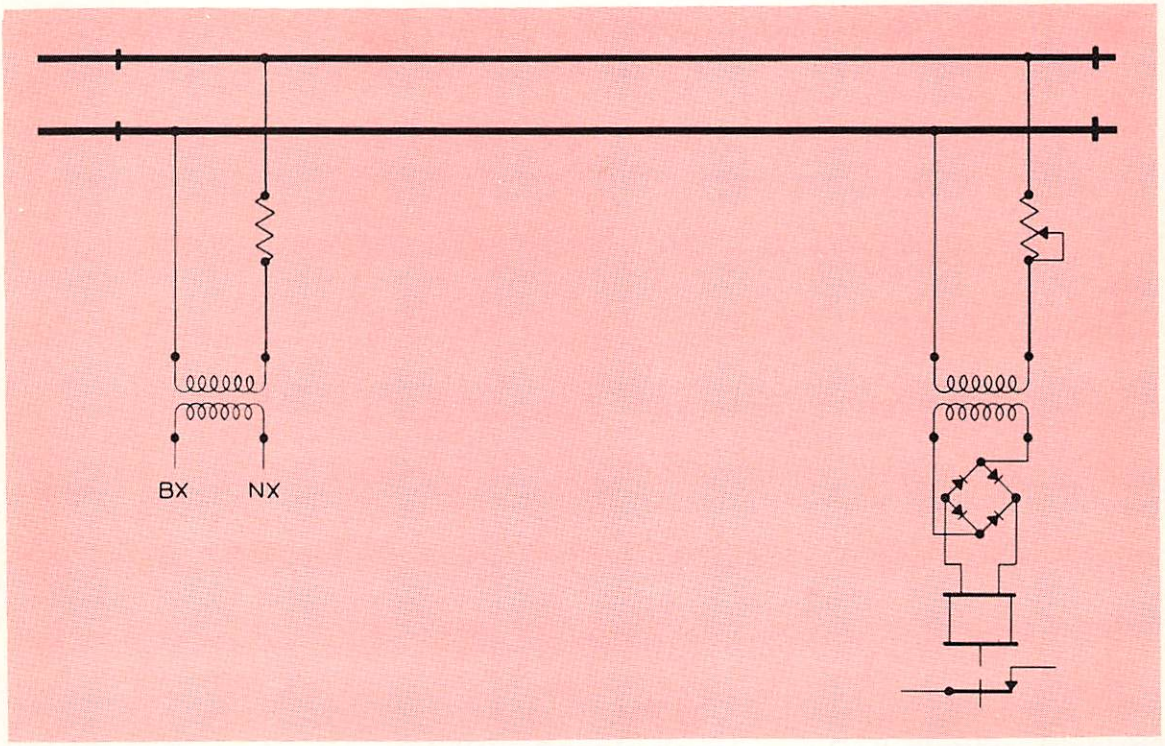

Figure 4. A-c. track circuit with d-c. relay for steam roads.

the current limiting device at the feed end. In addition to protecting the track transformer from excessive current, the adjustable reactor is a means of producing a phase shift between the local and track windings of the two-element relay. The ideal phase relation between the local and track windings is usually 90 degrees phase displacement.

Figure 4 shows another type of a-c. track circuit where a.c. is fed to the rails but a d-c. relay is used. A copper-oxide rectifier, connected between the relay and the rails, makes it possible to utilize the d-c. relay.

With good ballast conditions, such track circuits may be approximately 2000 feet long.

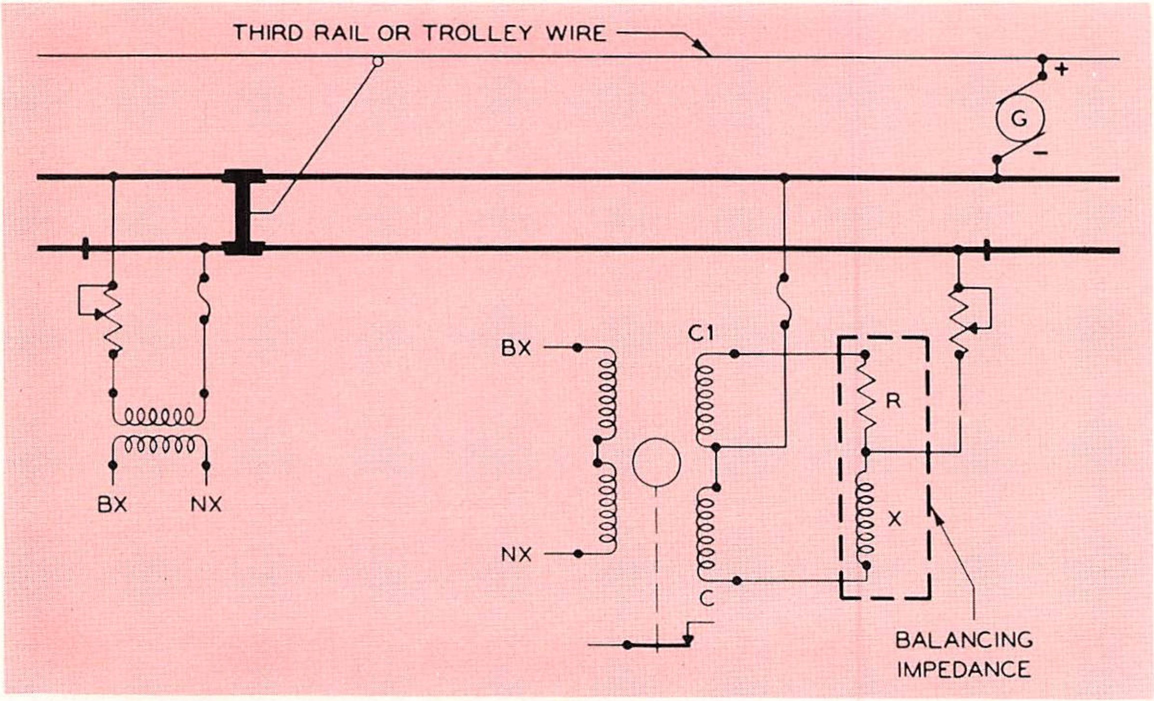

Figure 5. Single-rail a-c. track circuit with d-c. propulsion.

A-C. TRACK CIRCUITS FOR ELECTRIC ROADS USING D-C. PROPULSION

Here the problem is to isolate track sections as required for track circuits and yet not interfere with the propulsion return current which must flow from one section to another. This may be done in two ways, by using: (a) single-rail track circuits, wherein the insulated joints are provided in only one rail, the other rail being left electrically continuous for the propulsion return current, or (b) double-rail track circuits with reactor bonds to carry the propulsion current around the insulated joints yet restrict the flow of the signal current from one side of the track circuit to the other and from one track circuit to another.

Figure 5 shows the single-rail track circuit. Note that the series path through the track transformer secondary, the signal rail, and the relay is in multiple with the propulsion-return rail. If this series path is of low resistance, considerable propulsion current will flow through it, possibly damaging the transformer or relay windings. The resistors are used to limit the flow of propulsion current through this path. The balancing impedance also serves to keep the propulsion d.c. from interfering with the operation of the a-c. track relay.

Single-rail track circuits of this type have the disadvantage of confining the propulsion-return current to one rail, or of requiring an additional return conductor to be run parallel to the track. Poor bonding of the return rail may also force excessive propulsion return current through the track transformer secondary and through the relay windings. Such track circuits are usually limited in length to about 1000 feet.

Figure 6 shows the double-rail a-c. track circuit for use with d-c. propulsion current. Here reactor (impedance) bonds allow the propulsion current to flow around the insulated joints but restrict the flow of the track circuit current.

Figure 7 shows bonds with two windings, connected like an autotransformer. The energy is fed to the rails in series with an adjustable capacitor. This capacitor is used to set the track circuit at approximate resonance, and it also acts as a current limiting device when the track circuit is occupied.

At the relay end, a similar bond and capacitor are provided and adjusted

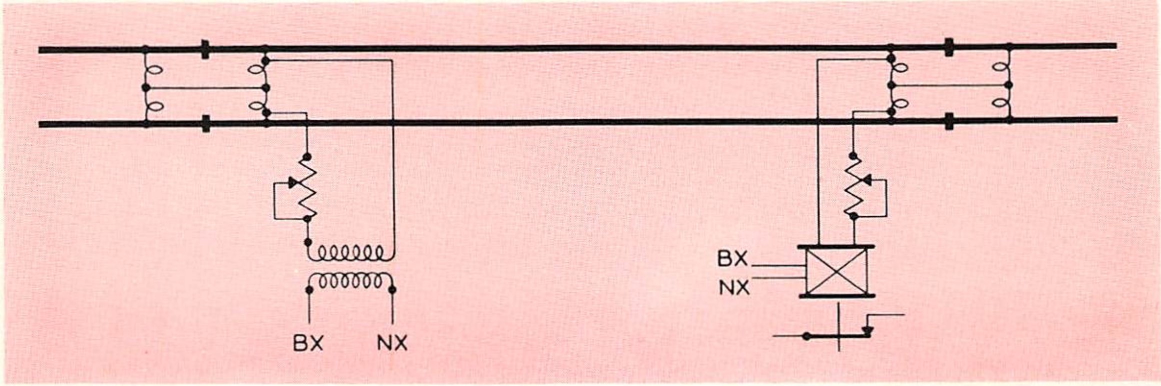

Figure 6. Double-rail a-c. track circuit with d-c. propulsion.

so that the rail to rail impedance is a maximum at the track circuit frequency.

When properly adjusted, this arrangement will maintain its shunting characteristics over a wider range of ballast resistance and will have lower resistance in the propulsion circuit than can be had with single-wound bonds such as shown in Figure 6.

A-C. TRACK CIRCUITS FOR ELECTRIC ROADS USING A-C. PROPULSION

When alternating current is used for propulsion, the track circuits should be operated from a different frequency, a frequency as much higher than the propulsion frequency as it is economically practical to have it - bearing in mind the increased energy consumption of the track circuits at higher frequencies. In selecting the two frequencies to be used, care must be taken to separate the signaling frequency as far as possible from not only the basic propulsion frequency but also from certain harmonics thereof. Your G-R-S representative will, at your request, make specific recommendations on frequency separation based on your particular operating conditions.

A satisfactory arrangement for a-c. propulsion is the double-rail track circuit with reactor bonds, very similar to the circuit shown in

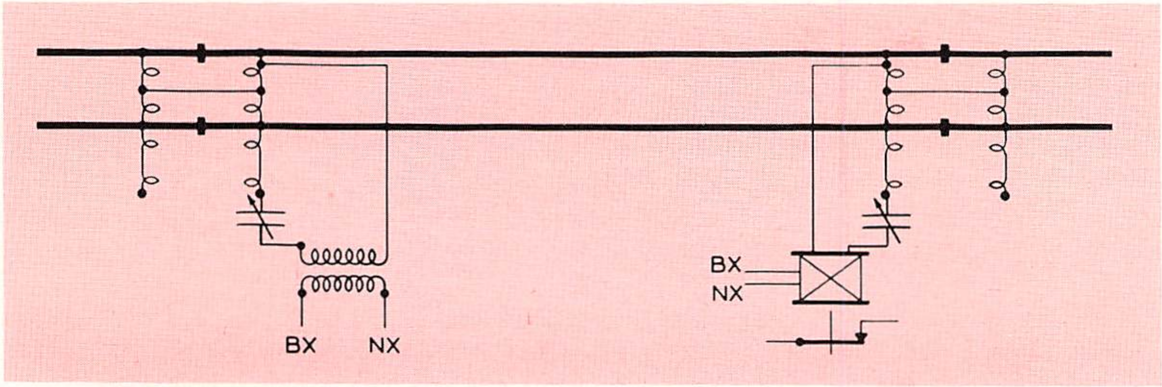

Figure 7. Double-rail a-c. track circuit for electric roads with d-c. propulsion, showing use of condenser with reactor bonds.

Figure 6. The reactor bonds operate on the same principle as for d-c. propulsion except that they are smaller, as a-c. propulsion voltages are usually higher and the currents the bonds must carry are correspondingly lower. Unbalancing troubles are less likely to occur than with d-c. propulsion, as the bonds tend to automatically balance the load between the two return rails.

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RAILROAD CROSSING

AUTOMATIC BLOCK SYSTEMS

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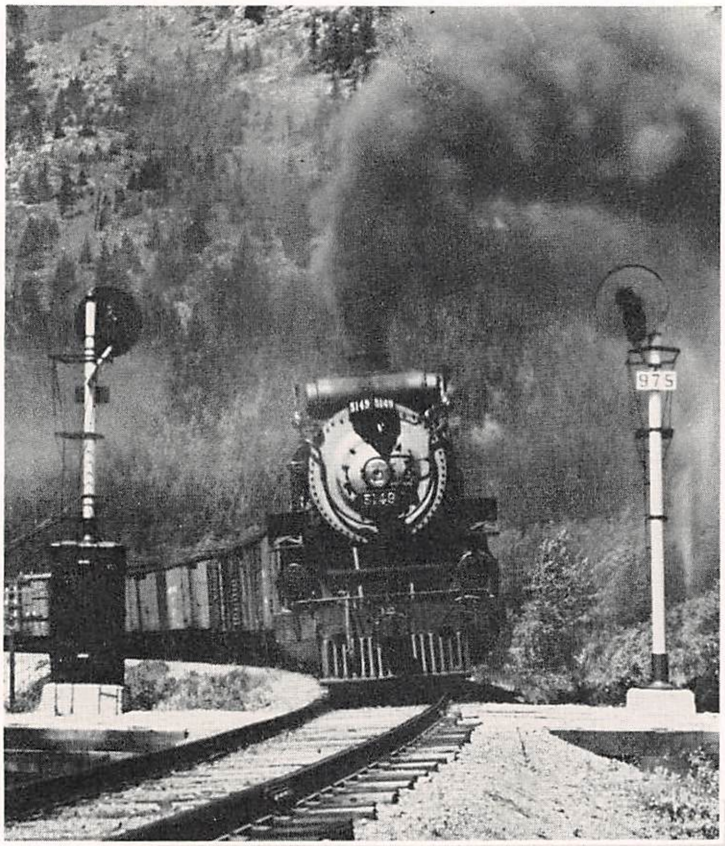


Figure 8a. Absolute permissive block signals on the Canadian Pacific Railway provide either-direction operation on single track.

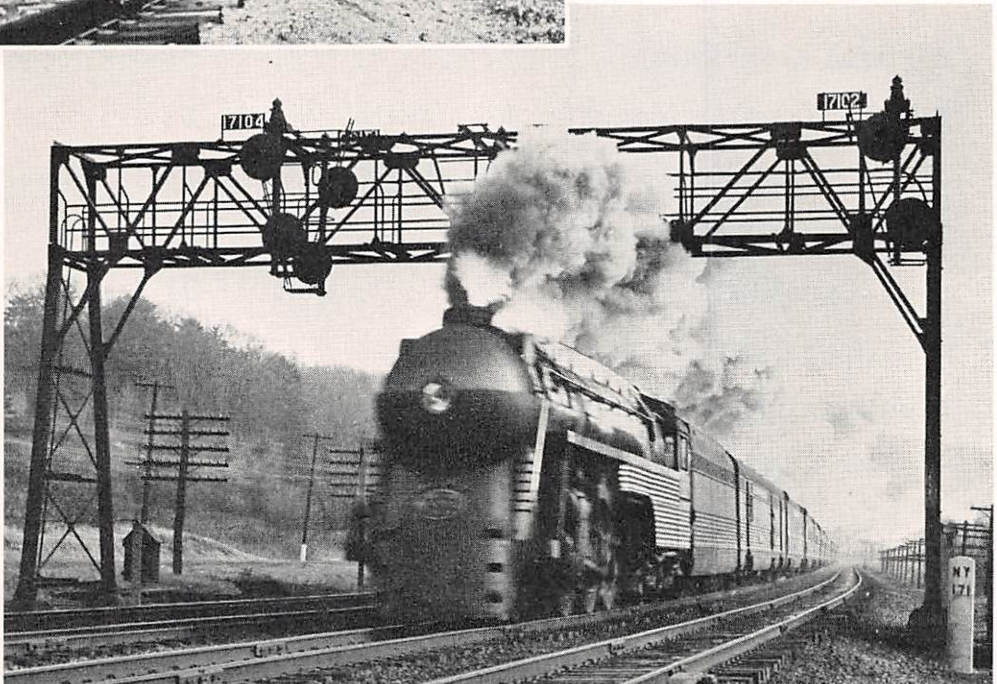


Figure 8b. These New York Central System tracks have automatic block signals arranged for single-direction operation.

AUTOMATIC BLOCK SYSTEMS

GENERAL DESCRIPTION

An automatic block signal system is a series of consecutive blocks governed by block signals usually operated by electricity and actuated by a train or by certain conditions affecting the use of a block.

A block signal is a fixed signal located at the entrance to a block to govern trains entering and using that block. A fixed signal is a signal of fixed location indicating a condition affecting the movement of a train.

An automatic block system may be for single or for multiple track. In the single-track system, the track is signaled for train operation in both directions. In the multiple-track system, the tracks are usually signaled for train operation in one direction only. Sometimes traffic conditions are such that it is worthwhile to have one or more of the tracks signaled for train operation in both directions.

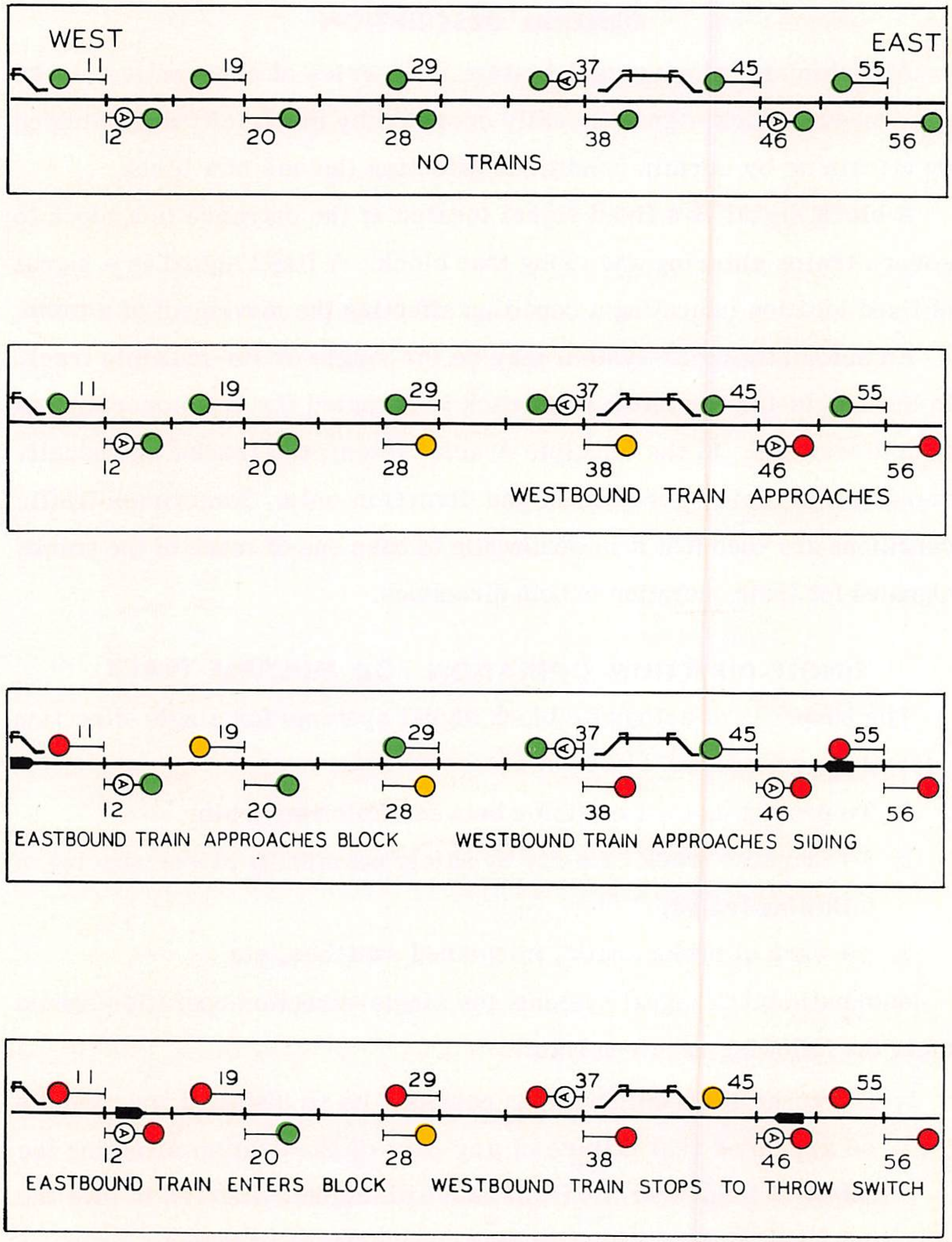
SINGLE-DIRECTION OPERATION FOR MULTIPLE TRACK

The purposes of automatic block signal systems for single-direction operation are:

1. To protect against collision between following trains.
2. To increase track capacity by safely permitting closer spacing of following trains.
3. To warn of broken rails, misplaced switches, etc.

Automatic block signal systems for single-direction operation should meet the following requirements:

1. The apparatus shall, so far as possible, be so installed and circuits so arranged that failure of any part of the system affecting the safety of train operation will cause all signals affected to give the most restrictive indication that circumstances require.
2. Signals shall be located uniformly, preferably to one side of and adjoining the track to which they refer.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A

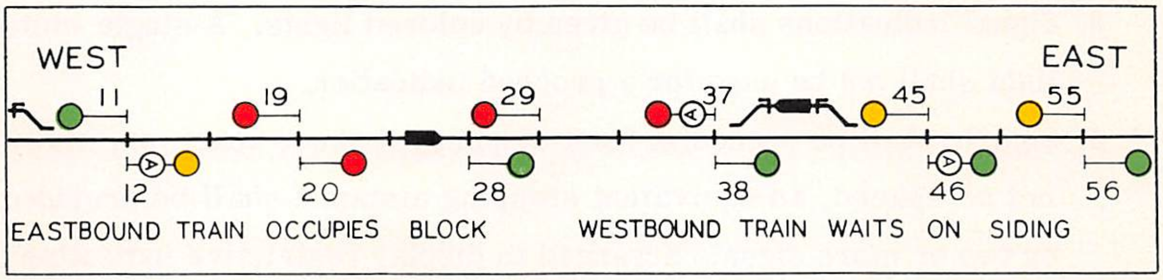
NO TRAINS

WESTBOUND TRAIN APPROACHES

EASTBOUND TRAIN APPROACHES BLOCK WESTBOUND TRAIN APPROACHES SIDING

EASTBOUND TRAIN ENTERS BLOCK WESTBOUND TRAIN STOPS TO THROW SWITCH

Figure 9. Sequence of operating events in absolute permissive block system. Signals are shown spaced braking distance apart for following moves.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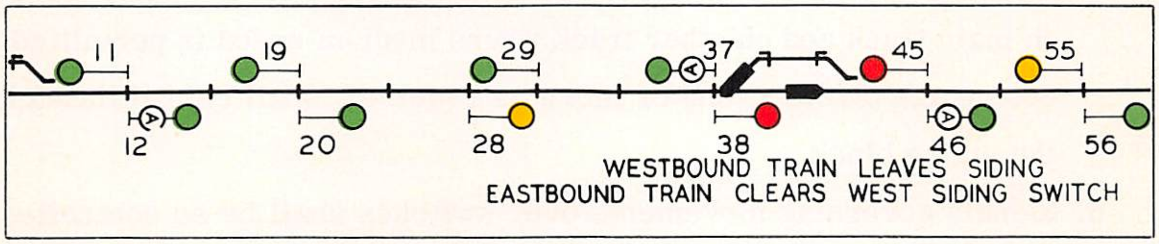
EASTBOUND TRAIN OCCUPIES BLOCK WESTBOUND TRAIN WAITS ON SIDING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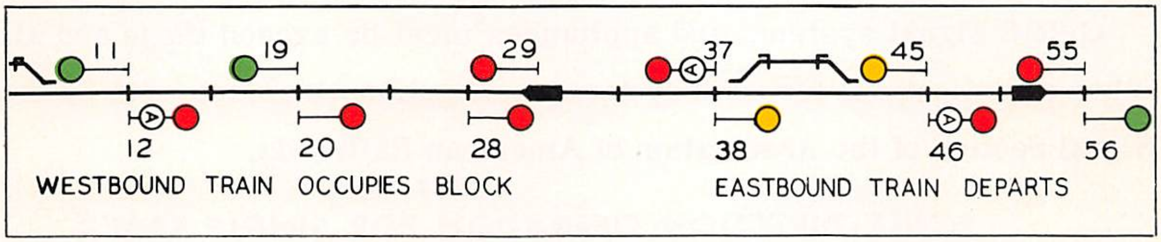
WESTBOUND TRAIN LEAVES SIDING
EASTBOUND TRAIN CLEARS WEST SIDING SWITCH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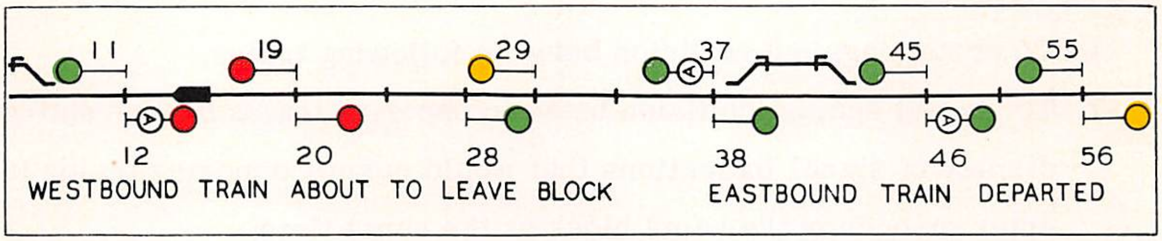
WESTBOUND TRAIN OCCUPIES BLOCK EASTBOUND TRAIN DEPARTS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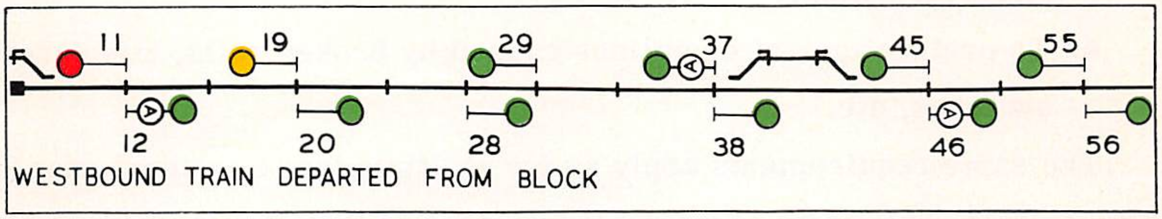
WESTBOUND TRAIN ABOUT TO LEAVE BLOCK EASTBOUND TRAIN DEPARTED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WESTBOUND TRAIN DEPARTED FROM BLOCK

3. Signal indications shall be given by colored lights. A single white light shall not be used for a proceed indication.
4. Signals shall be spaced at least stopping distance apart, or, where not so spaced, an equivalent stopping distance shall be provided by two or more signals arranged to display restrictive indications approaching the signal where the train has to stop.
5. Signals shall be automatically controlled by continuous track circuits on main track and on other track where medium speed is permitted. Such track circuits, one or more as required, shall extend through the entire block.
6. Signals governing movements over switches shall be so controlled that proper restrictive indications will be displayed when one or more such switches are not in proper position.

G-R-S signal systems and appliances meet or exceed these and all other specifications for such systems and appliances as set forth by the Signal Section of the Association of American Railroads.

EITHER-DIRECTION OPERATION FOR SINGLE TRACK

The purposes of automatic block signal systems for either-direction operation are:

1. To protect against collision between following trains.
2. To protect against collision between opposing trains by preventing display of signal indications that would permit opposing trains to enter or occupy the same block at the same time.
3. To increase track capacity by safely permitting closer spacing of following trains.
4. To protect against conditions caused by broken rails, misplaced switches, etc.

The same requirements apply as for multiple-track systems except that signals shall be so arranged and controlled that proper restrictive indications will be provided to protect both following and opposing movements.

Absolute permissive block signaling, a G-R-S development, is a system in which trains may follow each other from block to block as though with multiple-track, single-direction, automatic block signaling. Opposing train movements are governed by absolute or "stop-and-stay" signals, the block for which extends from siding to siding. For following movements, the track between sidings is divided into two or more blocks, as traffic conditions may require. Entry into these blocks is governed by intermediate signals. These are also commonly called permissive signals, as "stop; then proceed" is their most restrictive indication.

Figure 9 shows what happens when one train meets another in absolute permissive block signaling territory. The initial entry of a train into a siding-to-siding block causes all opposing signals (including the absolute signal at the opposite end of the block) to display their most restrictive aspects. This establishes the direction of traffic. As the train advances, the signals in its rear change from red to yellow to green, thus enabling following trains to follow as if the main track were one of a multiple-track line. After the train has passed out of the siding-to-siding block, the absolute signal permitting a train to move in the opposite direction will clear. This train will then in turn establish an opposite direction of traffic, and other trains may follow it.

MULTIPLE-ASPECT SIGNALING

Multiple-aspect signaling is the term generally applied to 3-block, 4-indication and to 4-block, 5-indication signaling. Figure 9 shows the 2-block, 3-indication system; that is, two blocks ahead must be clear before a signal can display a clear aspect. Figure 10 shows 3-block, 4-indication signaling compared with the 2-block, 3-indication system.

As shown in Figure 10, with 3-block, 4-indication signaling a train can proceed on clear indications closer to the preceding train than is possible with the 2-block, 3-indication system; yet stopping distance is equal in both systems.

Multiple-aspect signaling uses more signals and spaces them closer than the 2-block system. It gives enginemen information more frequently and thus allows trains to follow more closely. You get greater track capacity and faster average train speeds.

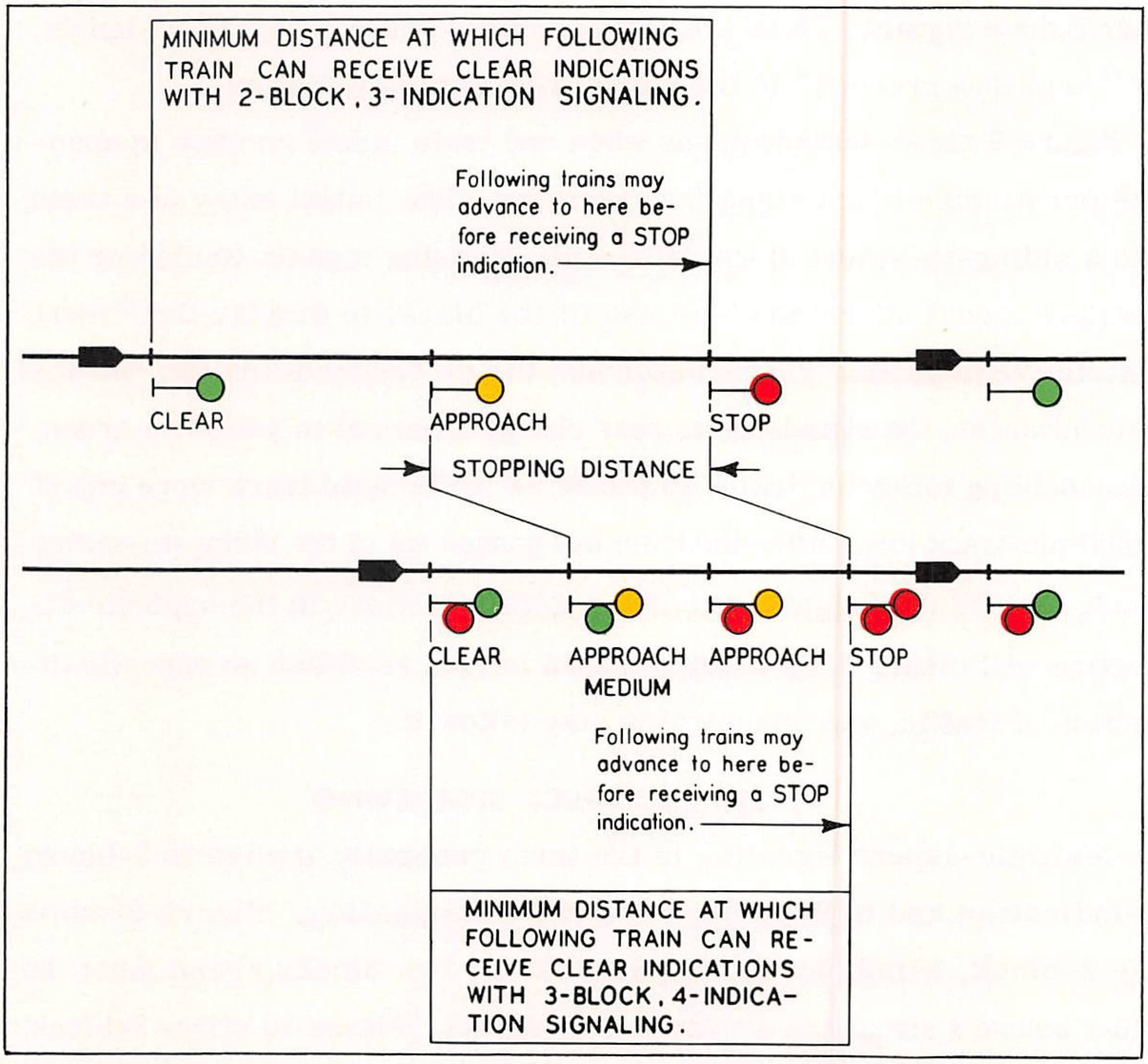
MINIMUM DISTANCE AT WHICH FOLLOWING TRAIN CAN RECEIVE CLEAR INDICATIONS WITH 2-BLOCK, 3-INDICATION SIGNALING.
Following trains may advance to here before receiving a STOP indication.
CLEAR
APPROACH
STOP
STOPPING DISTANCE
CLEAR
APPROACH MEDIUM
APPROACH
STOP
Following trains may advance to here before receiving a STOP indication.
MINIMUM DISTANCE AT WHICH FOLLOWING TRAIN CAN RECEIVE CLEAR INDICATIONS WITH 3-BLOCK, 4-INDICATION SIGNALING.

Figure 10. Typical spacing of trains with 2-block, 3-indication signaling (top) compared with 3-block, 4-indication signaling.

Multiple-aspect signaling is widely used to meet conditions such as these:

1. Heavy traffic.
2. Steep descending grades.
3. In approach to interlocking plants where interfering movements or speed restrictions may delay traffic.
4. Where a few trains (such as modern high-speed passenger trains) travel much faster than the rest of the traffic.

A-C. SIGNALING

G-R-S automatic block signal systems are available for operation by alternating current or by direct current, whichever better suits the requirements of the installation. Alternating current signaling may be used for the following reasons:

1. Electric railways use a-c. track circuits so that the propulsion current will not interfere with the signal system.
2. Foreign currents (from parallel electric lines, etc.) have less effect on a-c. track circuits than on steady-energy d-c. track circuits.
3. When a.c. is required for the track circuits, it is usually more convenient to use it to operate all other functions too.

The main parts of any a-c. signaling system are:

1. Energy supplies, main and reserve.
2. Transmission line.
3. Line transformers with protecting equipment, such as fused cutouts, lightning arresters, etc.
4. Signals.
5. Signal-control line with circuits and appliances such as relays, arresters, etc.
6. Track circuits with track relays, transformers, current limiters,

insulated rail joints, switch-rod insulation, etc. On roads with d-c. or a-c. traction current, impedance (reactor) bonds are also required, except where single-rail a-c. track circuits are used.

7. Switch protecting apparatus, such as switch circuit controllers, etc.
8. Housings for signal appliances, such as relays, secondary transformers, lightning arresters, fuses, terminals, and related wiring.

In modern a-c. signal systems, only the track circuits are operated directly from a.c. Signal-control and repeater-relay circuits are operated from rectified a.c. This arrangement is recommended for the following reasons:

1. Local and line circuits may be low voltage d.c. (full-wave rectified a.c.). D-c. relays and associated appliances may be used.
2. D-c. relays, signal mechanisms, and related appliances cost less, are smaller in size, and require less maintenance than equivalent a-c. apparatus.
3. D-c. relays may be had in a greater variety of operating characteristics to suit special circuit requirements.
4. Circuits extended over line wires, and especially through extended lengths of cable, are not as likely to be falsely energized (such as by inductance) when operation is d.c., or a.c. rectified at the a-c. source.
5. D-c. relays, signal mechanisms, etc. require less energy than similar a-c. appliances.

D-C. SIGNALING

In general, direct-current signaling is preferable. With direct-current operation you will usually have simpler circuits, appliances of comparably lower cost, minimum maintenance and replacement expense, and, with standby battery, dependable operation even under adverse conditions.

AUTOMATIC BLOCK SYSTEMS

The main parts of any d-c. signal system are:

1. An energy supply, such as rectified a.c., primary batteries, or storage batteries.
2. Signals.
3. Signal-control line with related circuits and appliances. Where coded track circuits are used the line wire can be eliminated, as the signal controls are transmitted through the rails.
4. Track circuits with track batteries, resistors, insulated rail joints, switch-rod insulation, etc.
5. Switch protecting apparatus, such as switch circuit controllers, etc.
6. Housings for signal appliances, such as relays, lightning arresters, fuses, terminals, batteries, rectifiers (if used), and related wiring.

ADDITIONAL PROTECTION WITH BLOCK SIGNALING

Other forms of protection can be conveniently added to block signaling systems, such as detection of floods, fire, dragging equipment, and earth or rock slides.

Flood Detection

Flood detection provides signal protection for high water conditions that may be weakening bridges, undermining fill, or otherwise creating hazards. Such systems consist of a float-operated contactor installed in locations dictated by experience. The device is so arranged that when the water reaches a predetermined level the float will rise far enough to open the contacts and thus open the signal circuit and put the associated signals to stop. Such devices are usually trip contacts that, once operated, must be manually reset.

Fire Detection

Fire detection, desirable in wooden trestles, wood-lined tunnels, snow sheds, etc., usually consists of fusible wire in series with the signal

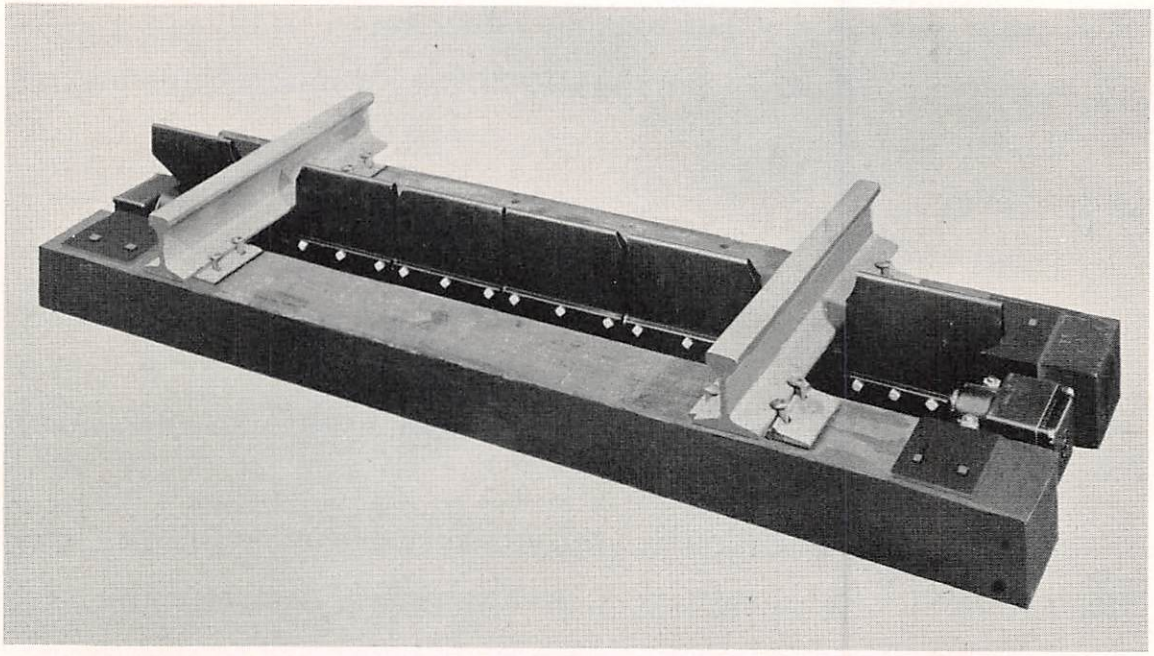

Figure 11. G-R-S self-resetting dragging equipment detector.

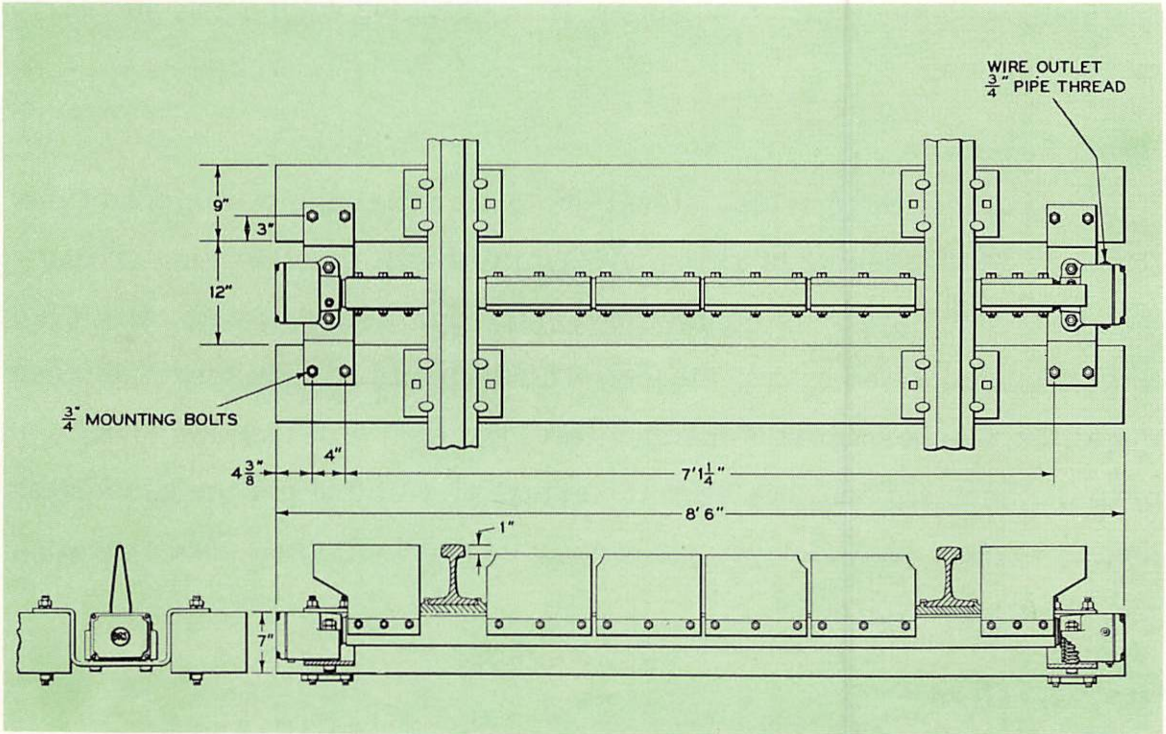
WIRE OUTLET
$\frac{3}{4}$" PIPE THREAD
9"
3"
12"
$\frac{3}{4}$" MOUNTING BOLTS
$4\frac{3}{8}$"
4"
$7'1\frac{1}{4}$"
8' 6"
1"
7"

Figure 12. Layout of dragging equipment detector.

circuit. This wire melts in the presence of fire, opening the signal circuit.

Dragging Equipment Detection

The G-R-S self-resetting dragging equipment detector, Figure 11, is non-directional, available for use by traffic moving either way over the tracks. It will reset itself after each operation and blades are easily replaced if damaged. The detector is simple in construction and operation. All the mechanism is down between the ties in one compact unit where it is easy to service.

The dragging equipment detector consists of a shaft supported by bearings at either end. Bearings are housed in compartments which are spring mounted on brackets attached to the ties.

Six blades are bolted to the shaft. A torsion bar extending through the shaft serves to keep the shaft in position so that the blades remain vertical and will return to their vertical position after having been deflected by dragging equipment.

A normally closed contact, housed in one of the two bearing compartments, is arranged so that it will open whenever the shaft is rotated 5 degrees or more in either direction. This contact usually controls a stick circuited relay which, in turn, controls the circuits associated with an appropriate dragging equipment signal or other indication as desired.

The opposite bearing compartment houses a simple device for adjusting the torque as required. Thus the detector may be adjusted so that it will not open its contact when struck relatively light blows, as, for example, by icicles hanging from the running gear.

Figure 12 shows a typical layout of the dragging equipment detector.

Slide Detection

Slide detector fences, Figure 13, are used for protection against derailment from land slides. They protect the right-of-way through cuts, at the base of rocky slopes, and in tunnels.

Fences are constructed and located according to local conditions in the slide area. They are usually installed in sections up to 400 feet long. The usual practice is to use a five-foot, pole-suspended fence mounted from one to two feet above the ground level to allow small stones to pass under without operating the fence.

A Model 8 switch circuit controller, Figure 14, (see Pamphlet 751 for description) is mounted on a steel mast between each fence section. The fence is loosely stapled to all intermediate fence posts to allow for lateral movement. When a slide occurs, the fence movement is transmitted through an operating pipe and trigger arrangement to operate the controller. The line control circuit of the governing signals is opened to display a stop indication.

If the fence is located in automatic block territory, the controller is included in the line control circuit. Outside automatic block territory, it may be used in series with special automatic signals.

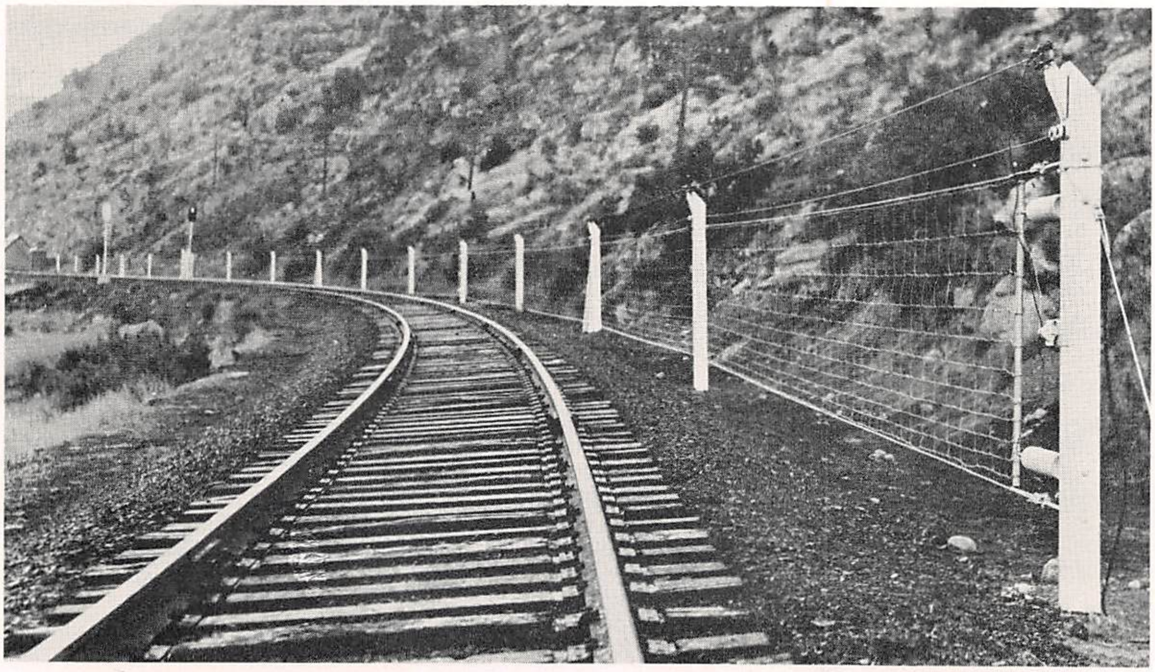

Figure 13. Slide detector fence.

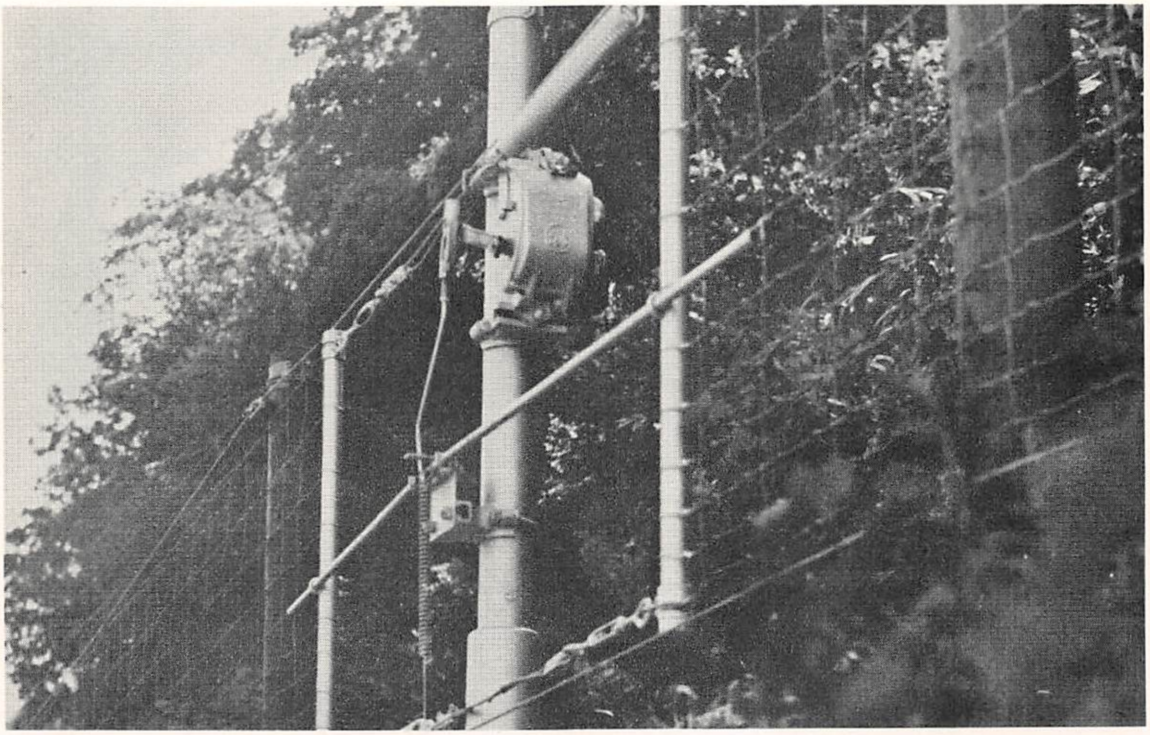

Figure 14. Circuit controller location.

Protection for Non-shunting Track Vehicles

An indicator system can be applied to any signaling system using continuous track circuits. The system provides protection for the operators of non-shunting track vehicles (called "motor cars" in the U. S.) by enabling them to find out whether track circuits to their rear are occupied.

This is done by installing a lamp with pushbutton, Figure 15, at each point along the wayside where a check is desirable. The operator stops at each of these points and pushes the button. If the lamp lights, the track circuits checked are unoccupied. If the lamp does not light, he knows the track is occupied and can take suitable precautions.

The main body of the lamp housing is of cast aluminum. All joints are securely sealed with non-hardening cement so that the entire unit is waterproof and insect proof. The socket is the standard single-contact

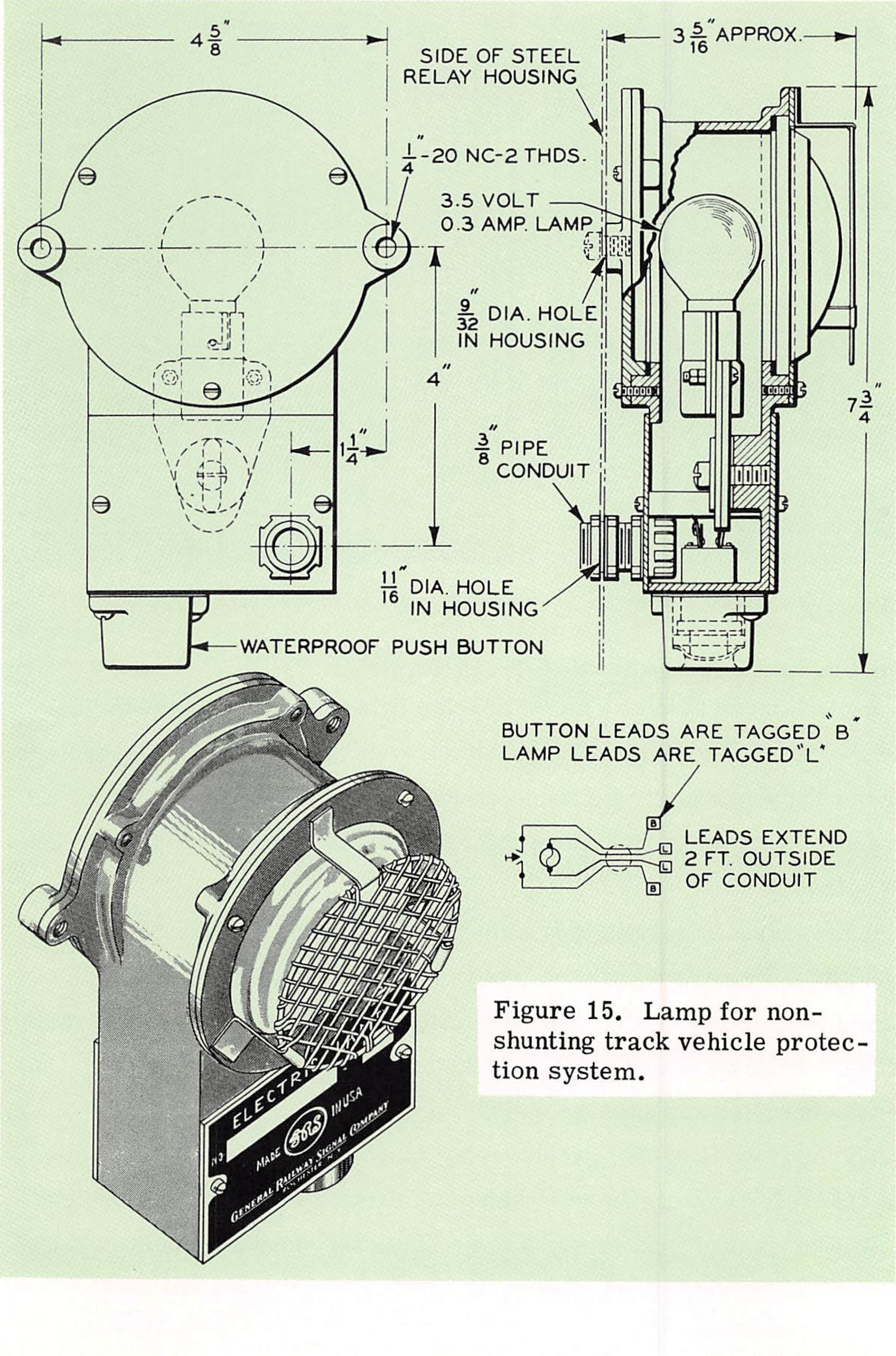
4 5/8"
SIDE OF STEEL RELAY HOUSING
3 5/16" APPROX.
1/4"-20 NC-2 THDS.
3.5 VOLT 0.3 AMP. LAMP
9/32" DIA. HOLE IN HOUSING
4"
7 3/4"
1 1/4"
3/8" PIPE CONDUIT
11/16" DIA. HOLE IN HOUSING
WATERPROOF PUSH BUTTON
BUTTON LEADS ARE TAGGED "B"
LAMP LEADS ARE TAGGED "L"
B
L
L
B
LEADS EXTEND 2 FT. OUTSIDE OF CONDUIT
ELECTRIC
NO.
MADE GRS IN USA
GENERAL RAILWAY SIGNAL COMPANY
ROCHESTER, N.Y.

Figure 15. Lamp for non-shunting track vehicle protection system.

candelabra bayonet-base type. Any lamp bulb of this type may be used if the bulb diameter does not exceed 1-3/8 inches.

The clear, standard optical lens is 3-1/2 inches in diameter. A heavy wire guard protects the lens.

The single-contact, normally open pushbutton is of fully weatherproof construction. It is rated at 110 volts. Two-foot leads of number sixteen flexible stranded wire are supplied already connected to the lamp and pushbutton terminals.

Installation details are shown in the accompanying illustration. Only three holes need be drilled in the side of a steel relay housing, two for the mounting screws and one for the 3/8-inch pipe conduit.

110-31

CODED TRACK CIRCUIT CONTROL

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General description 42

Single-direction operation for multiple track 43

Either-direction operation for single track . 44

GENERAL DESCRIPTION

Current supplied to a coded track circuit is continuously interrupted or ''coded'' so that the code responsive track relay makes and breaks its contacts in response to the ''on'' and ''off'' periods of the track current. To clear a signal, the code-responsive track relay must continuously make and break its contacts. If the armature stops (with contacts either open or closed), the signal goes to stop. The train shunt resistance need only hold the track current to a point just below the relay's pickup value.

Now let us contrast this with the steady-energy track circuit. In a steady-energy track circuit, the shunt resistance must lower the current to the dropaway value of the track relay. A code-responsive track relay stops operating as soon as the current through it falls below its normal operating value.

Since the pickup current of any relay is considerably higher than its dropaway current, it follows that (given the same track circuit conditions) we can use higher voltage at the feed end of a coded track circuit and still get proper shunting sensitivity. Higher feed voltage makes possible extension of the track circuit, still maintaining shunting sensitivity equal to or better than with steady-energy circuits.

It is usually safe to assume that when coded circuits are replacing steady-energy circuits which have operated satisfactorily, lengths of coded circuits can be twice that of the steady-energy circuits.

Another advantage of coded track circuits is that different code rates may be used, each rate effecting a different signal control. 75-code (75 "on-off" periods per minute) may be used to indicate caution, while 180-code may be used to indicate proceed (no code or steady current puts the signal to stop). Thus the rails carry the signal controls. You don't need signal-control line wires.

CODED TRACK CIRCUIT CONTROL

SINGLE-DIRECTION OPERATION FOR MULTIPLE TRACK

Figure 16 shows schematically how coded track circuits may be used on one track of a double-track automatic block signaling system. Note that all three signal aspects are controlled directly by the track circuits. Such a system requires no signal-control line wires. If more aspects are needed, additional codes can be added.

When required, code can also be sent in the opposite direction to that shown in Figure 16. The "on" periods of such a code are transmitted during the "off" periods of the main code. This is called inverse code. It is used for approach locking, annunciation, etc. - wherever you want the train to send a control ahead of it.

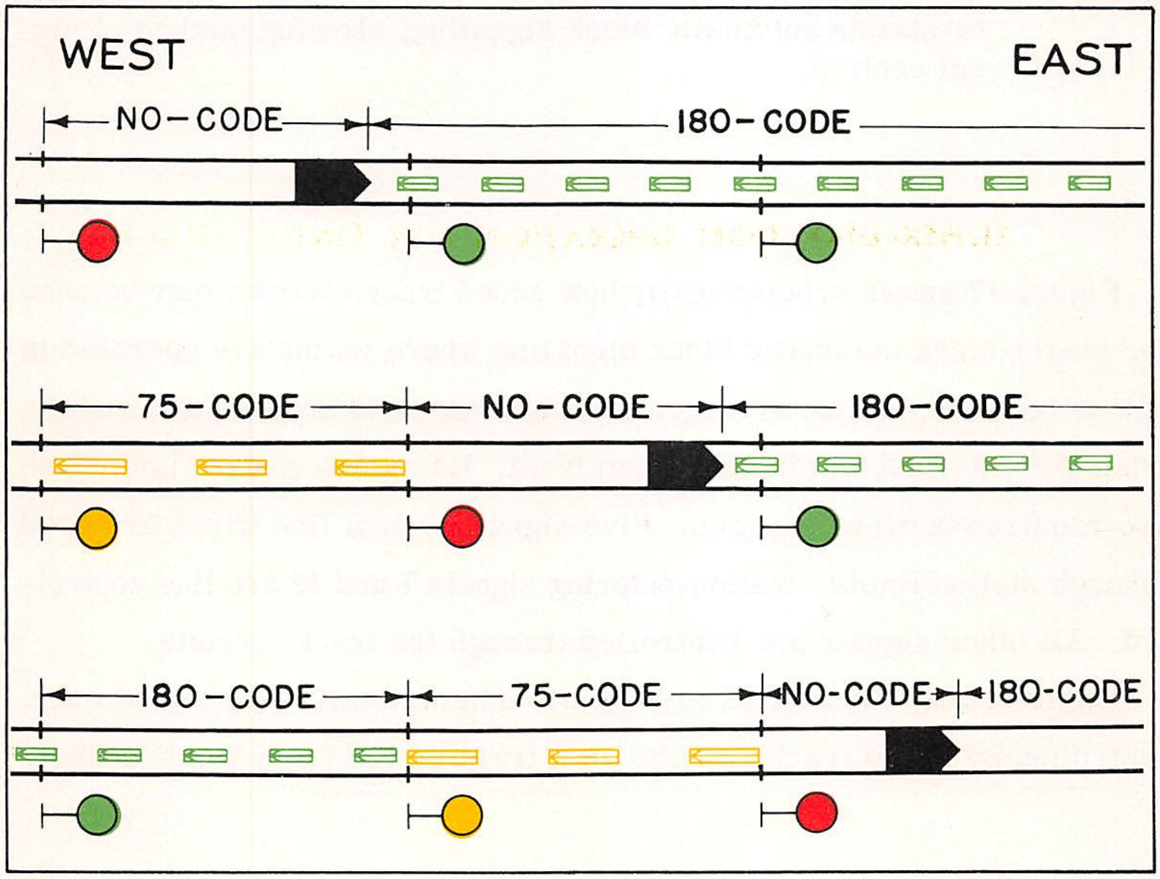


Figure 16. Coded track circuit control as used on 2-block, 3-indication automatic block signaling for double track, train shown moving from West to East.

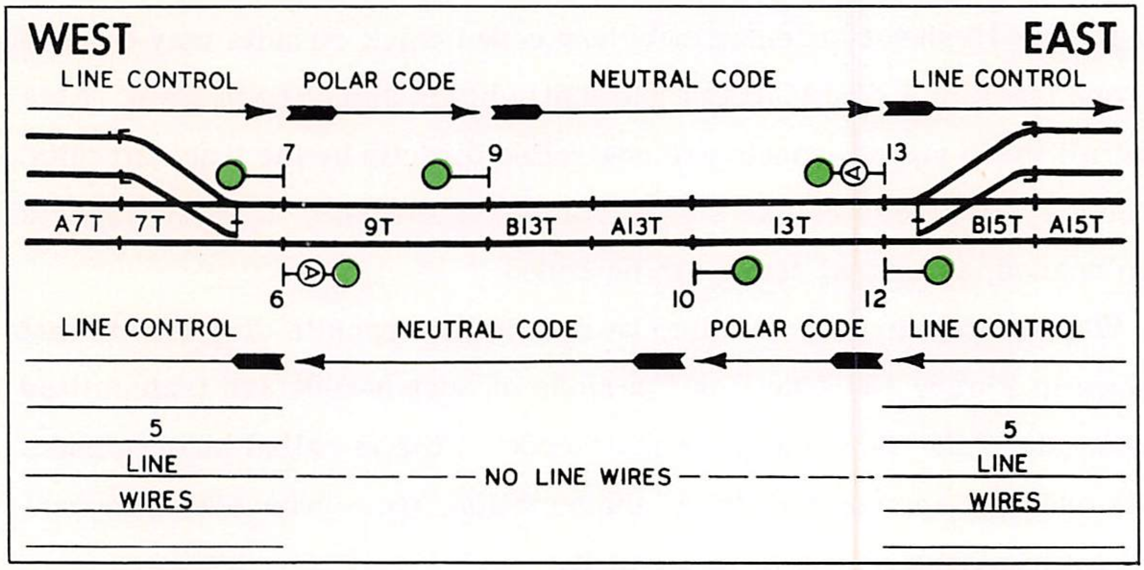

WEST
EAST
LINE CONTROL
POLAR CODE
NEUTRAL CODE
LINE CONTROL
7
9
13
A7T
7T
9T
B13T
A13T
13T
B15T
A15T
6
10
12
LINE CONTROL
NEUTRAL CODE
POLAR CODE
LINE CONTROL
5 LINE WIRES
NO LINE WIRES
5 LINE WIRES

Figure 17. Coded track circuit control as used on single-track, station-to-station automatic block signaling, showing method of signal control.

EITHER-DIRECTION OPERATION FOR SINGLE TRACK

Figure 17 shows schematically how coded track circuits may be used for single-track automatic block signaling where trains are operated in both directions. In this arrangement, code impulses are sent alternately, from West to East and from East to West. No signal-control line wires are required between stations. Five signal-control line wires are used through station limits. Station-entering signals 7 and 12 are line controlled. All other signals are controlled through the track circuits.

The following Figures 18 to 23 show schematically how signals are controlled by coded track circuits as a train moves from West to East.

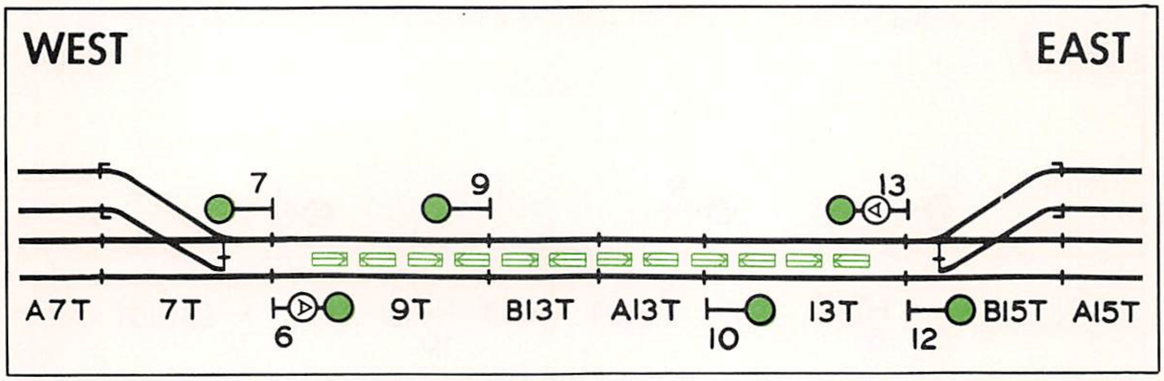

WEST
EAST
7
9
13
A7T
7T
6
9T
B13T
A13T
10
13T
12
B15T
A15T

Figure 18.

As shown in Figure 18, when all track circuits are unoccupied, code impulses can feed back and forth between East and West, keeping all signals clear.

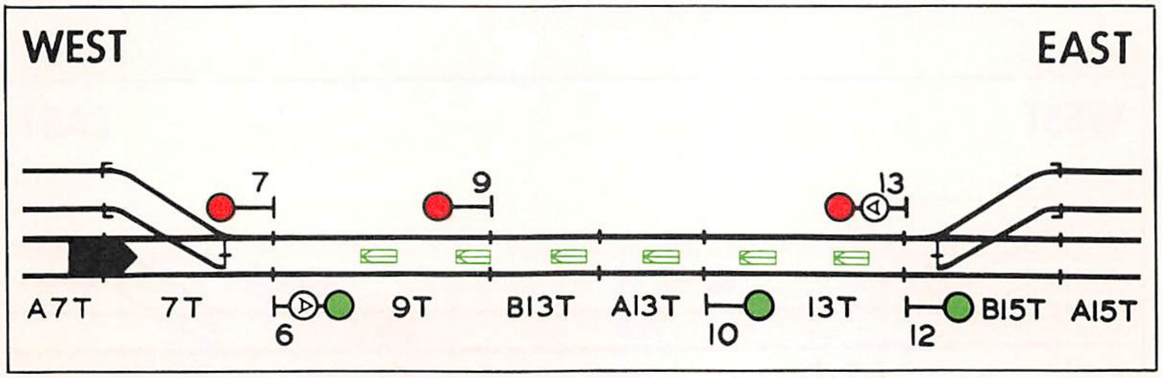

WEST
EAST
7
9
13
A7T
7T
6
9T
B13T
A13T
10
13T
12
B15T
A15T

Figure 19.

As soon as a train shunts track circuit A7T, Figure 19, the code feeding toward East ceases, and all westbound signals go to stop. Code continues to feed toward West, however, thus holding all eastbound signals clear.

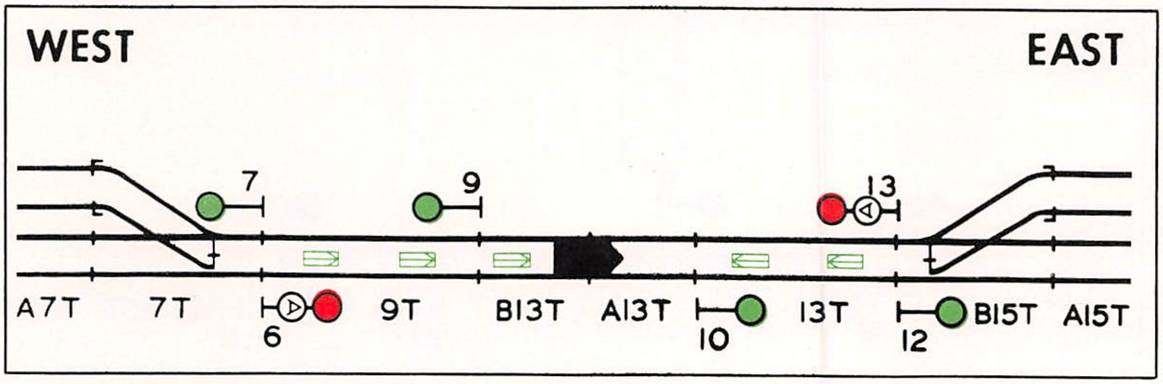

WEST
EAST
7
9
13
A7T
7T
6
9T
B13T
A13T
10
13T
12
B15T
A15T

Figure 20.

As the train proceeds eastward, Figure 20, signal 6 protects its rear and code feeds eastward behind it, causing signals 7 and 9 to clear. Signal 10 provides an approach indication for signal 12.

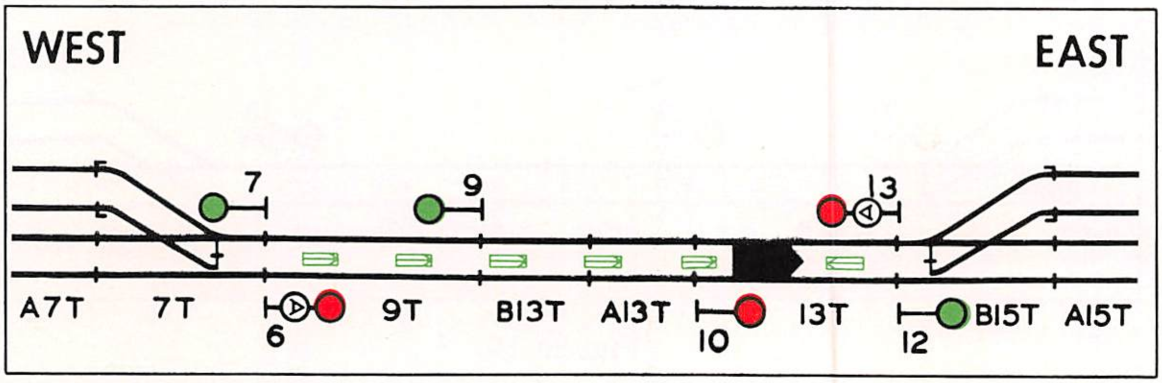

WEST
EAST
7
9
13
A7T
7T
6
9T
B13T
A13T
10
13T
12
B15T
A15T

Figure 21.

When the train enters 13T, Figure 21, signal 10 goes to stop.

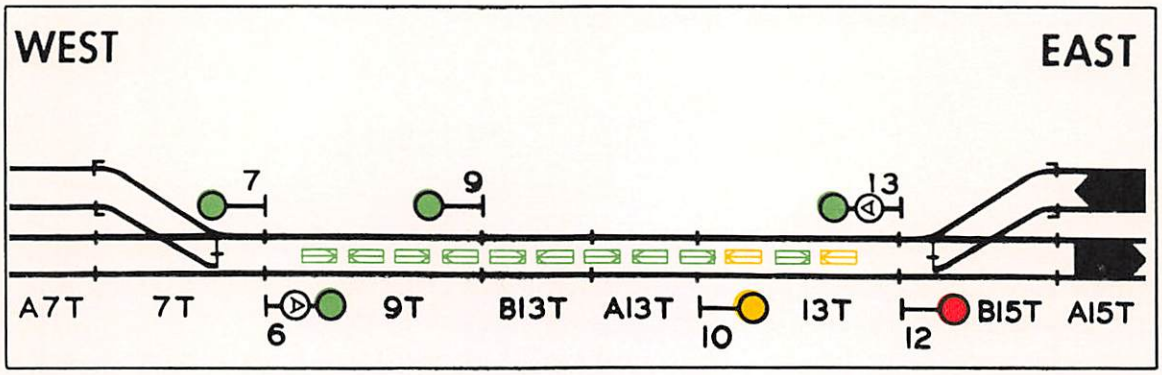

WEST
EAST
7
9
13
A7T
7T
6
9T
B13T
A13T
10
13T
12
B15T
A15T

Figure 22.

When the eastbound train clears the switch, Figure 22, code from West clears signal 13, and code feeding from East clears signals 10 and 6. Note that signal 10 goes to caution, not proceed, as signal 12 is at stop. This is done by polarizing the westbound code to signal 10 in accordance with the position of signal 12. Proceed aspects of signal 9 are controlled in the same way by the position of signal 7.

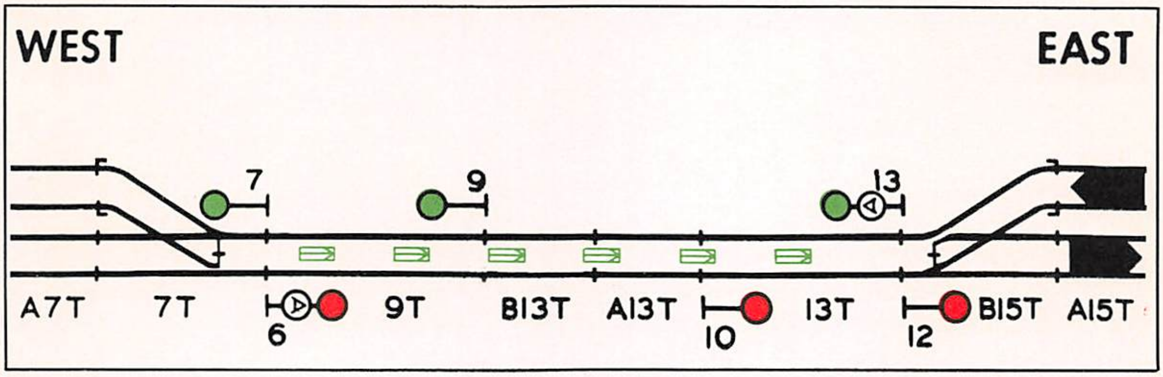
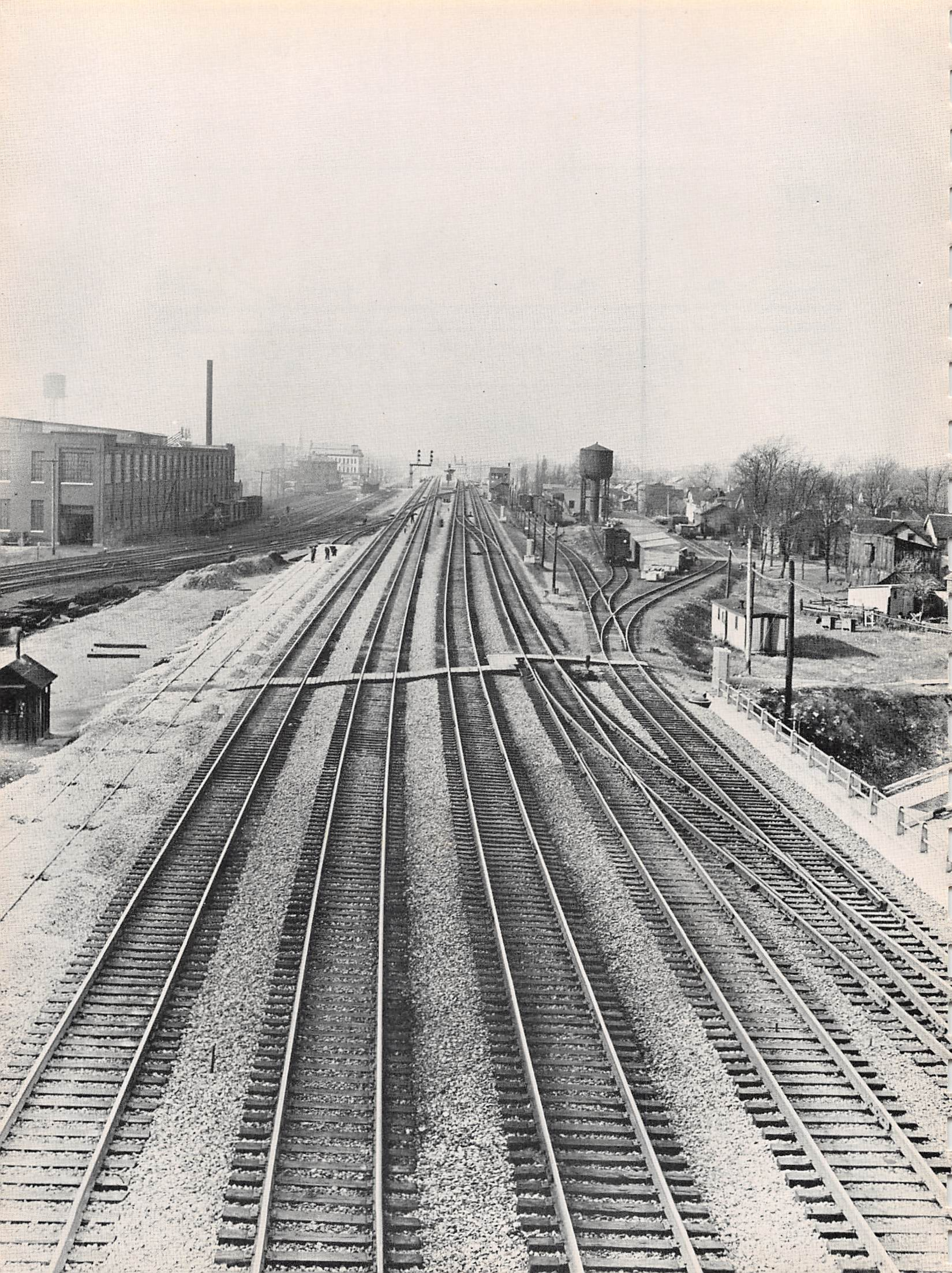

WEST
EAST
7
9
13
A7T
7T
6
9T
B13T
A13T
10
13T
12
B15T
A15T

Figure 23.

As soon as the switch is reversed, Figure 23, code from East ceases, all eastbound signals are put to stop, and the westbound train is free to take the main track toward West.



INTERLOCKING

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GENERAL DESCRIPTIONS

Interlocking is defined as, ''An arrangement of switch, lock and/or signal appliances so interconnected that their movements must succeed each other in a predetermined order.''

Interlocking is employed to facilitate and safeguard the movement of trains at terminals, junction points, railroad grade crossings, and drawbridges. The related appliances are so interlocked and controlled that setting up conflicting routes or clearing signals that would permit a train to enter an unsafe route, or taking away from a train a route or portion thereof into which the train has received a signal to enter, is prevented except as may be allowed by some predetermined procedure.

Interlocking may be accomplished by one of several methods:

1. Mechanical Interlocking. A system whereby all track functions (switches, switch locks, derails, bridge locks, etc.) and signals are operated manually by pipe-connected levers. These levers are provided with an arrangement of locking bars, dogs, tappets, cross locking and other apparatus by means of which the interlocking is effected between the levers of the interlocking machine, and these levers are so interconnected that their movements must succeed each other in a predetermined order.
2. Electro-Mechanical Interlocking. A system employing an interlocking machine which is a combination of mechanical and electrical levers. Thus, some units such as switches, switch locks, derails, bridge locks, etc., may be operated mechanically; and other units, such as signals, may be operated electrically. Signal selection (over switches, etc.) may be made electrically. Track circuits are usually employed in combination with electric locking. Electric locking consists of the combination of one or more electric locks and controlling circuits by means of which levers of an inter-

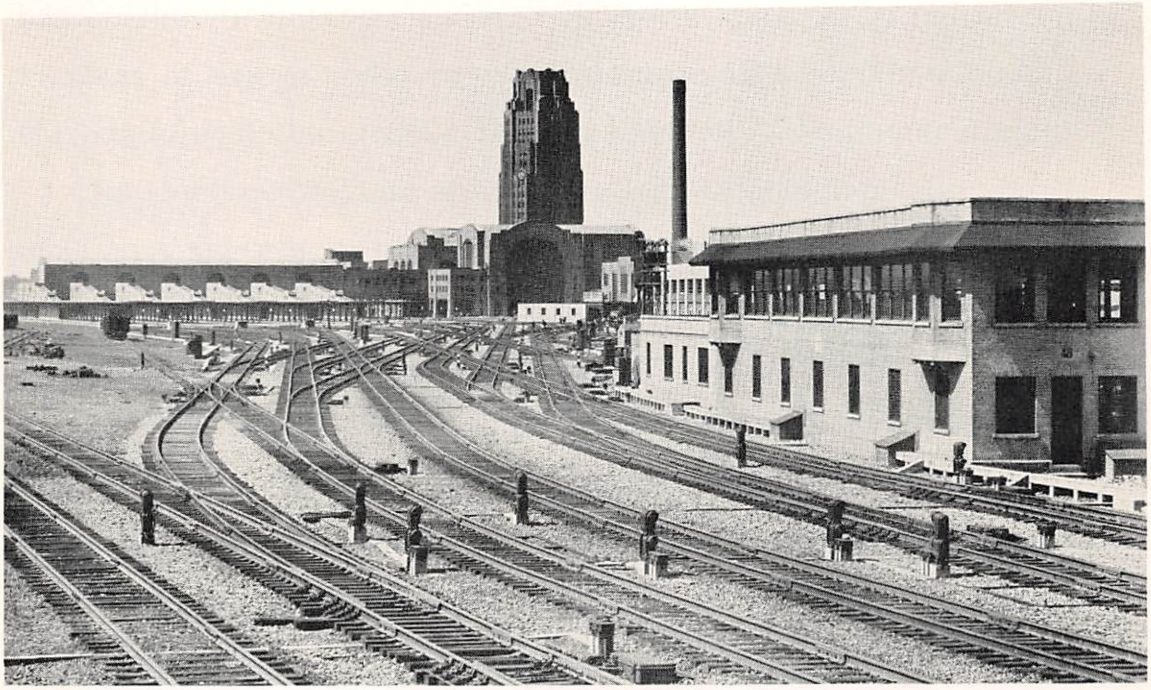

Figure 24. A large electric interlocking at Buffalo, New York, on the New York Central System.

locking machine, or switches or other units operated in connection with signaling and interlocking, are secured against operation under certain conditions, such as: approach locking, indication locking, switch lever locking, time locking, and traffic locking.

3. Electric Interlocking. A system employing an interlocking machine designed for operating and controlling the units electrically. The levers of such a machine are provided with mechanical locking (as described in 1), and electric locking is employed throughout.
4. Automatic Interlocking. An arrangement of electrically controlled and operated signals and associated appliances which function through the exercise of inherent control, as distinguished from those whose functions are controlled manually.
5. Relay Interlocking. A system employing a control machine designed to operate and control the units electrically (or with pneumatic

operation) by means of levers that are not mechanically interlocked and not provided with electric locks or other means to restrict their manipulation. Relays and their associated circuits provide protection equivalent to that provided in electric interlocking.

6. NX (eNtrance - eXit) Interlocking. A system bearing a marked resemblance to relay interlocking except for an important difference in the setting up of routes; that is, the method of controlling the individual switch and signal functions. This method consists of automatically selecting, controlling and operating all required functions upon the operator's identifying the point in the plant where a train is to enter and identifying the point where the train will leave.

The requisites of interlocking systems are the same as those for automatic block systems. In addition,

1. Track circuits shall be provided throughout interlocking limits, except when otherwise authorized.
2. Signals governing movements over switches, movable point frogs, and derails shall be so controlled that indications to proceed can be displayed only when such units are in proper position.
3. Mechanical locking to insure predetermined order of lever movement, or circuits to insure proper correlation of the units of the interlocking, shall be provided.
4. Except at automatic interlockings, signals which form a part of an automatic block signal system shall be controlled semi-automatically.
5. Approach or time locking shall be provided in connection with signals governing movements at high or medium speeds.
6. Electric switch locking shall be provided at manually operated interlockings, except when otherwise authorized.

7. Facing point locks or switch-and-lock movements shall be provided for mechanically operated switches, movable point frogs, or split-point derails.
8. Power switch operating and locking mechanisms shall be provided with means to indicate on interlocking or control machines when movement is completed and unit is locked.
9. Indication locking or equivalent shall be provided for approach signals of the semaphore type and power-operated home signals.
10. Movable bridges shall be equipped with mechanism to surface and align bridge and track accurately and fasten them securely in position.
11. When a movable bridge is protected by interlocking, provision shall be made to insure that movements of the bridge devices succeed each other in a predetermined order, and that the movable span, tracks, and switches within interlocking limits are locked in proper position.

In addition to the above requirements, it has long been the policy of the General Railway Signal Company to promote, insofar as is practical, the standardization of interlocking practices and equipment. In this way, interchangeability, modifications, and, in years to come, the modernization of plants may be made with maximum utilization of existing equipment Spare parts stock requirements are minimized, with a corresponding reduction of annual maintenance costs. As regards General Railway Signal Company's electric, automatic, relay, and NX interlocking systems, the simple, straightforward circuits, standardized wherever possible, have contributed immeasurably to years of satisfactory operation and ease of maintenance.

The type of interlocking plant to be installed is generally determined by the track layout, the number of functions to be operated and their

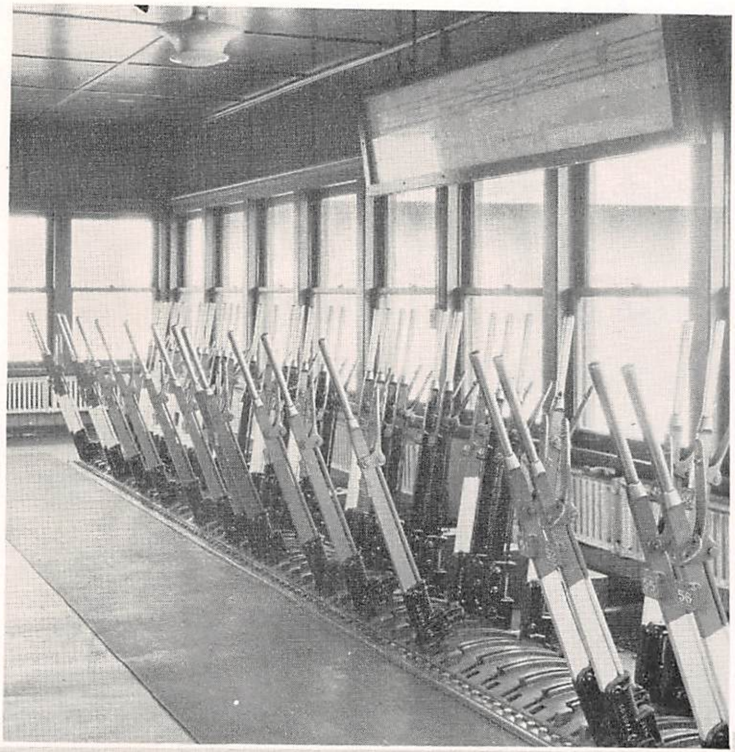

Figure 25. Mechanical interlocker on the New York Central.

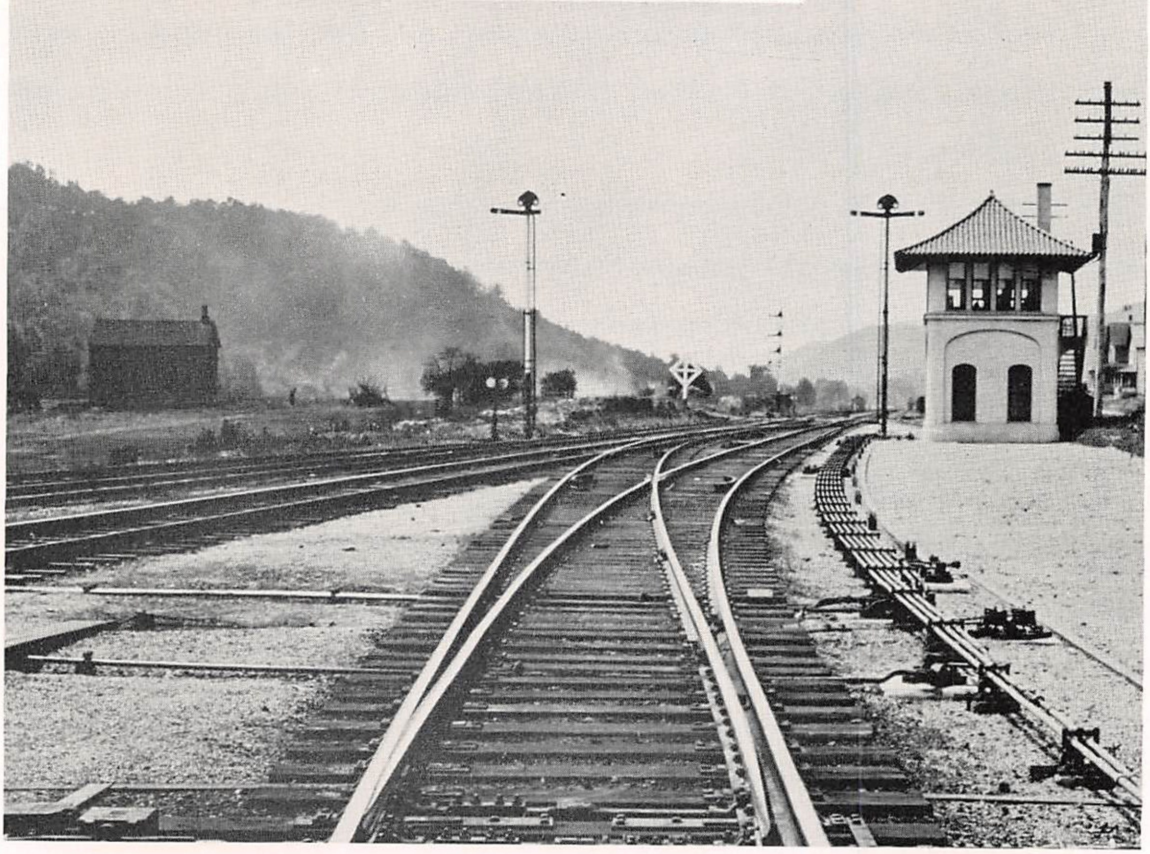

Figure 26. Mechanical interlocking on the Baltimore and Ohio.

distance from the selected control point, the nature and volume of traffic, and the facility of operation desired. General Railway Signal Company engineers will gladly assist you in making a study to determine which system will best suit the requirements of a particular location, both from the operating and the economic standpoint.

MECHANICAL INTERLOCKING

Mechanical interlocking comprises basically an interlocking machine, Figure 25, consisting of levers mounted in a frame. Each lever carries a latch, a spring-actuated device which holds the lever in either the normal or reverse position. The latch is connected to the locking bars carried in a locking bed. The locking bed interlocks the levers as required and enforces their movements in a predetermined order. In addition, the levers are connected to the outside functions by means of pipe lines, supported on pipe carriers, Figure 26. Cranks in the pipe lines change or reverse the throw, and compensators counteract the expansion and contraction caused by temperature changes. The spacing of the levers is standardized at 5 inches.

One lever is usually used for each function, switch, derail, or signal, except where switch-and-lock movements are not used. In the latter case, a separate facing point lock assemblage is provided which is operated by a lever other than the one used to throw the switch. Mechanical time locks are available for application to levers whose operation must be subject to a predetermined time-interval delay under certain conditions.

Mechanical interlocking, at one time used extensively in the United States and Canada, is rapidly being replaced by the more modern types of interlocking, such as relay interlocking. Only a few installations have been made in late years and these only at locations where a few functions exist and the frequency of operation is comparatively low.

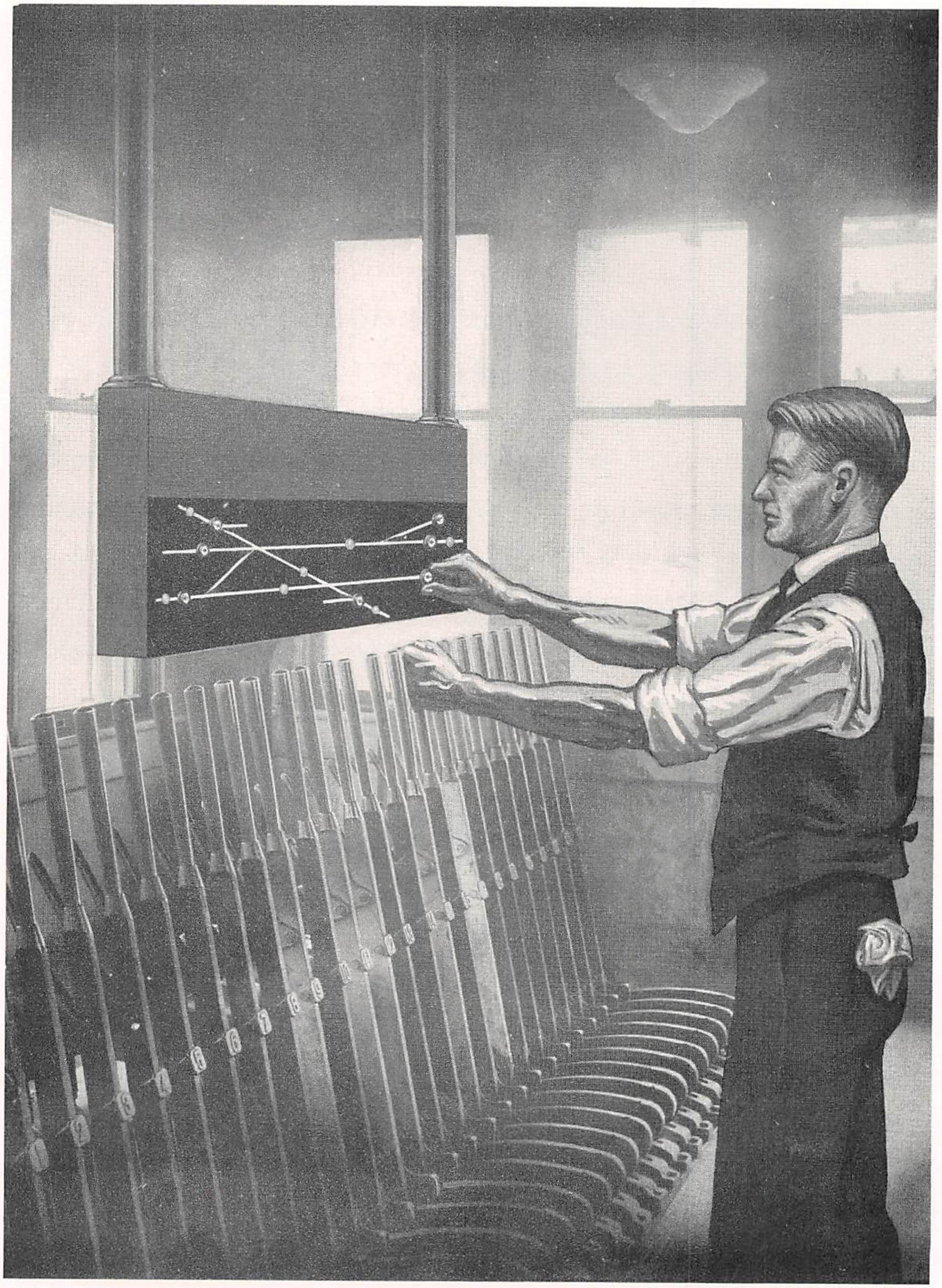

Figure 27. Electro-mechanical interlocking.

ELECTRO-MECHANICAL INTERLOCKING

As the name implies, an electro-mechanical interlocking employs an interlocking machine, Figure 27, which is a combination of an electrical and a mechanical machine. The levers used to control electrically operated functions are electrically interlocked with those controlling mechanically (or manually) operated functions.

The usual practice is to operate local switches, derails, movable point frogs, bridge locks, etc., and their respective facing point locks, by means of mechanical connections and to operate signals electrically. Track circuits are used, and, in conjunction with the signal operating and repeater circuits, detector, indication, approach and time locking may be effected as required. A track model board is usually provided, on which lights indicate track occupancy, approach, signal operation, lock, and such other conditions as desired.

With electrically controlled and operated signals, the selection of signals over contacts in switch circuit controllers or switch repeater relays becomes practical. One lever may control more than one signal, the desired signal being selected automatically by the position of switches over which the signal governs movements.

Electric lever locks and circuit controllers are available for use with either the electrical or mechanical levers. Manually operated time releases are available for use in circuits requiring time-element operation.

Electro-mechanical interlocking greatly expands the scope of the territory which can be controlled from an interlocker as compared with ordinary mechanical interlocking. Hence, it was widely used on American railroads and particularly in the rehabilitation of existing mechanical interlockers, where it was deemed necessary and desirable to install track circuits and electrically operated signals or to increase the scope of the plant.

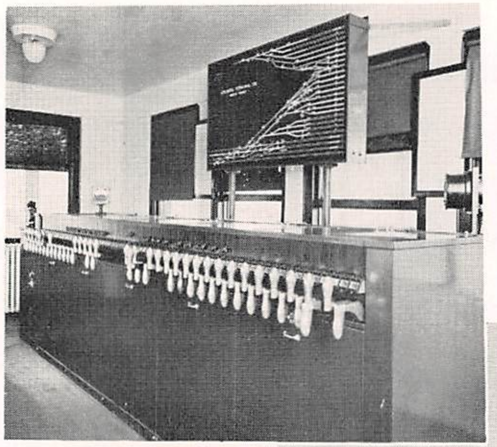

Figure 28. G-R-S Model 2 electric interlocking, Atlanta Terminal, on the Southern.

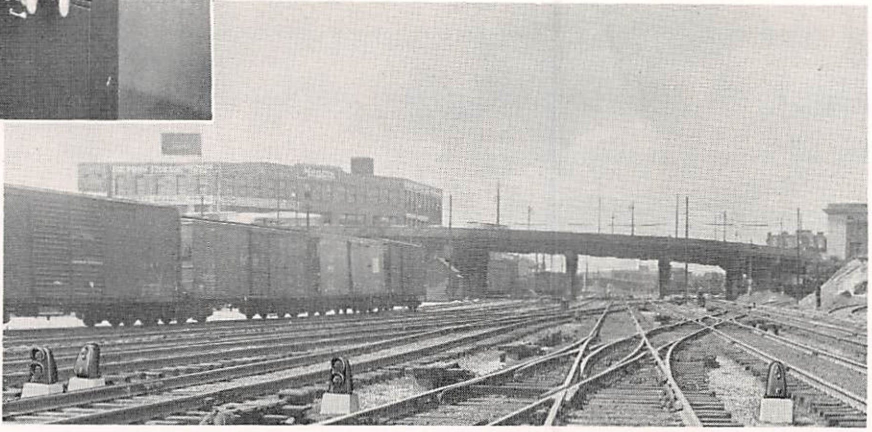

Figure 29. Model 5A switch machines and Type MD signals at Atlanta Terminal.

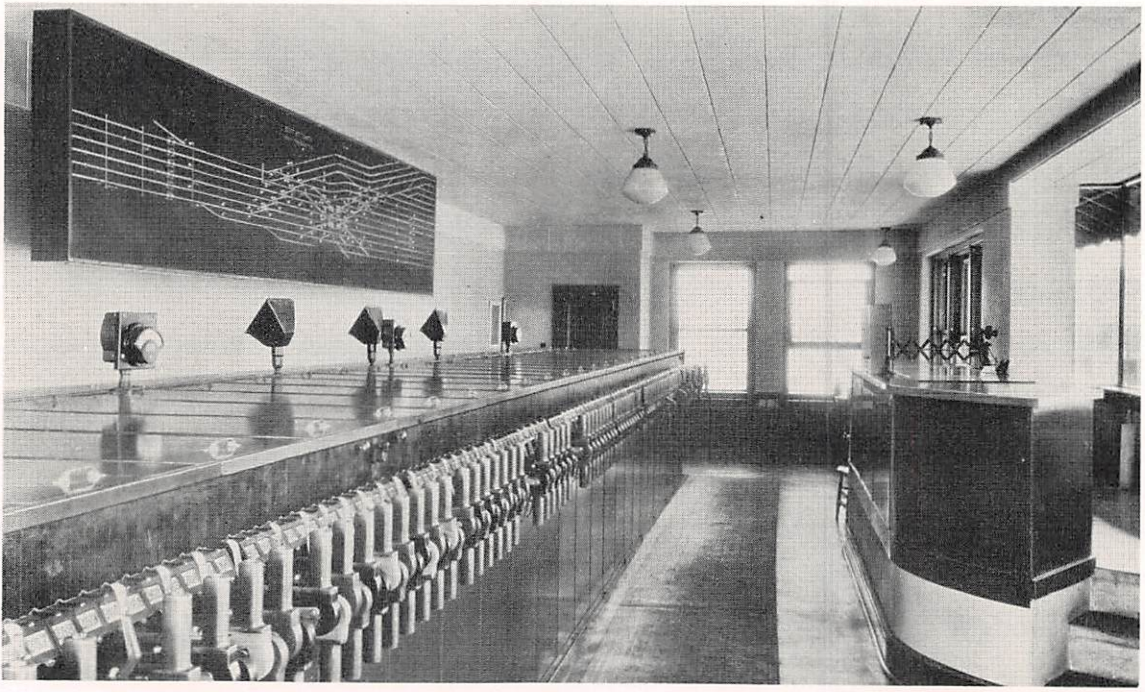

Figure 30. G-R-S Model 5 electric interlocking, Toronto Terminals Railway, Canada.

ELECTRIC INTERLOCKING

Electric interlocking is a type of power interlocking and, as the name implies, electricity is the operating energy. The essential elements for a complete electric interlocking system are a source of electrical energy, a machine with its levers and auxiliary apparatus for controlling switch and signal mechanisms, and apparatus for preventing unauthorized movement of an operated unit.

In electric interlocking, means are also provided to check the correspondence of the position of switches, signals or other controlled units with the position of their respective controlling levers. This is known as indication locking. The means employed to prevent the unauthorized movement of an operated unit is known as cross-protection.

In the system of electric interlocking introduced by the Taylor Signal Company* in 1900, the electrical energy for operating the unit is carried through contacts on the lever and over wires to the unit; the same wires being generally used for the return of the indication current for operating the indication locking. This system employs what is commonly known as the dynamic indication principle in which the energy for indication purposes is furnished by current generated by the momentum of the motor of the operated unit after it has completed its work of moving the switch or signal.

With electric interlocking, one lever is generally used for the control of each unit. Mechanical locking is provided between the levers to insure predetermined order of lever movement. A track model board is usually provided on which lights may be used to indicate track occupancy, approach, signal operation, lock, and such other indications as may be desired. Lamps, mounted in the machine and above the levers, may be

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*Predecessor of the General Railway Signal Company.

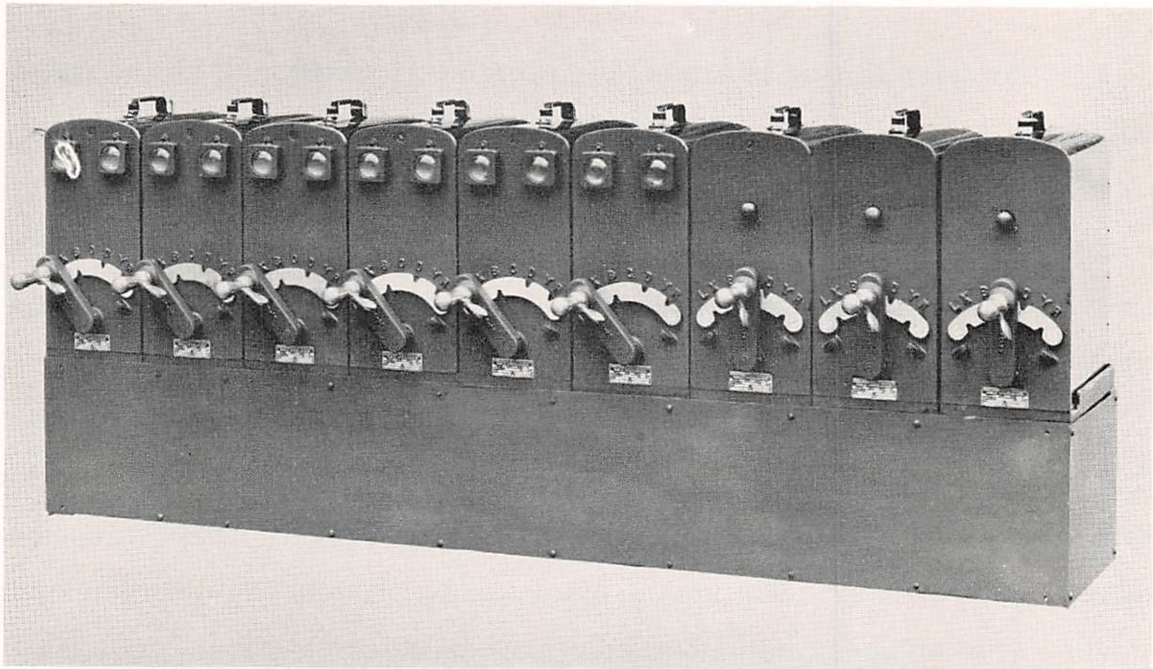


Figure 31. Table interlocker with vertical arrangement of locking.

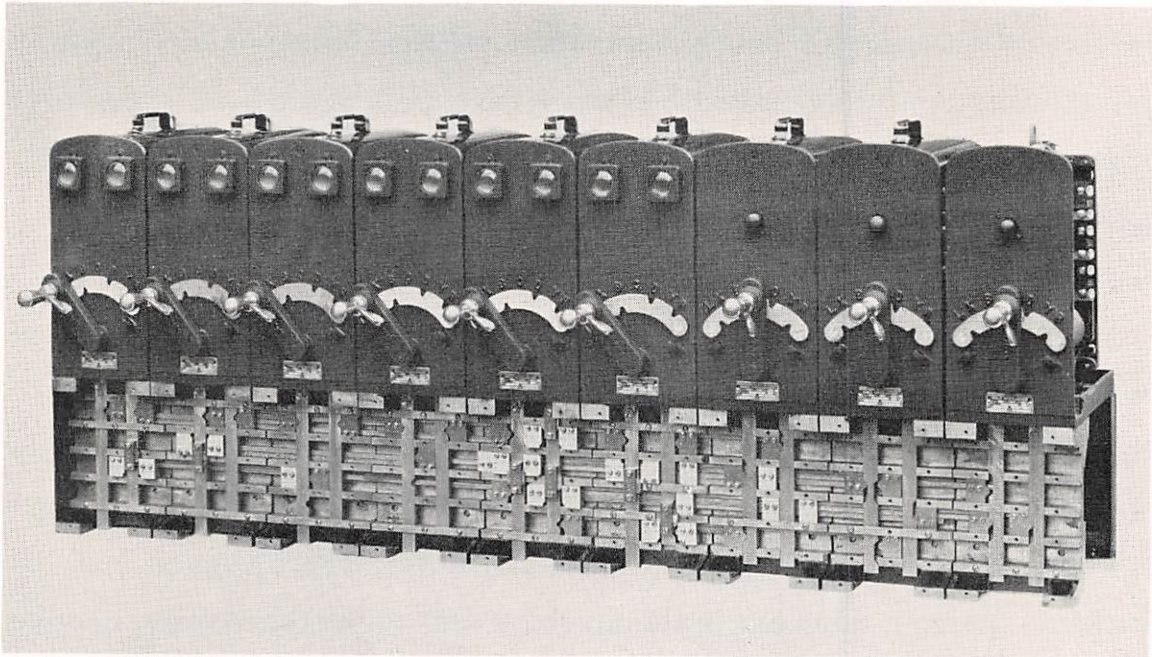


Figure 32. Table interlocker showing locking.

used with the electric locking to indicate whether the lever may or may not be moved.

Table Interlockers

The table interlocker is, as the name implies, a small electric interlocking machine that may be placed on a table or desk. It was designed primarily to control power-operated switches and associated signals from a remote point, but is by no means limited to this usage.

Each lever is equipped with a rotary circuit controller and may also be equipped with an electric lock and electro-magnetic indicators. The lock sectors on signal levers may be notched to provide indication locking protection. The lock sectors on switch levers may be notched to provide switch indication and approach and detector locking protection. Mechanical locking between levers, Figure 32, is usually provided but is optional.

Levers are so designed that one lever may be used alone, or two or more may be assembled side by side for the control of more extensive layouts.

AUTOMATIC INTERLOCKING

An automatic interlocking is an arrangement of signals and switches whose controls are interlocked like relay interlocking. The switches and signals function through the exercise of inherent controls as distinguished from those whose functions are controlled manually. Such an interlocking operates upon the approach of a train.

Automatic interlockings have been installed for signal protection of gauntlet tracks over bridges and through tunnels, at junctions of branch lines with main lines, at ends of two main tracks, at single- and multiple-track crossings, and other simple layouts. Many such installations provide interlocked signal protection where none previously existed and, in

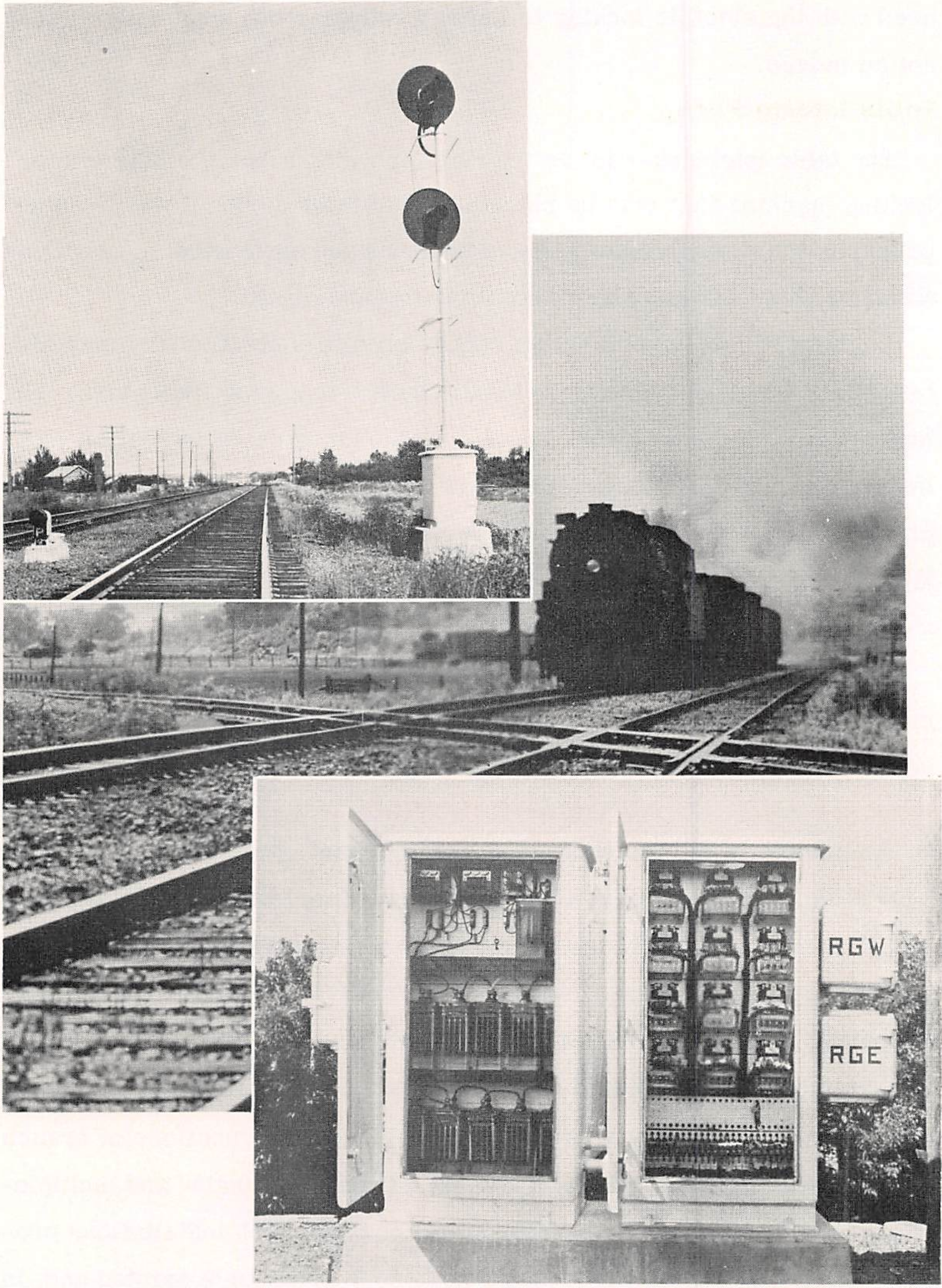


Figure 33. Automatic electric interlocking on the Denver & Rio Grande Western.

many cases, they have replaced manually operated interlockings. An automatic interlocking does not need attendants, an interlocking machine, or an interlocking station or tower. It eliminates these yearly operating and maintenance costs. Where no interlocked signal protection existed, automatic interlocking expedites traffic, usually by eliminating the train stops which are generally required at such non-interlocked points. Hence, they are recommended as an economic means to be considered for reducing operating expenses and expediting traffic.

Automatic interlockings were first installed about 1923. Since that time they have been widely used.

RELAY INTERLOCKING

The advent of relay interlocking was one of the greatest advances in the art of railway signaling. The transition from standard interlocking (employing mechanical locking between levers) to relay was gradual. The first applications were for the control of one or two functions by non-interlocked levers, with the equivalent of mechanical interlocking between the levers furnished by relays and their associated circuits. The improvements made in relays, and the development of relays with varied operating characteristics, made possible and practical the development of relay interlocking to its present high state of perfection. Records show that in America the transition to relay interlocking began in the late 1920's.

The advantages of relay interlocking are:

Increased speed and flexibility of manipulation and operation - automatic route cancellation, for example, is easily arranged.

For large layouts, fewer operators are required than with the older forms of interlocking.

Relay interlocking is better adapted to the control and operation of remote locations than older forms of interlocking.

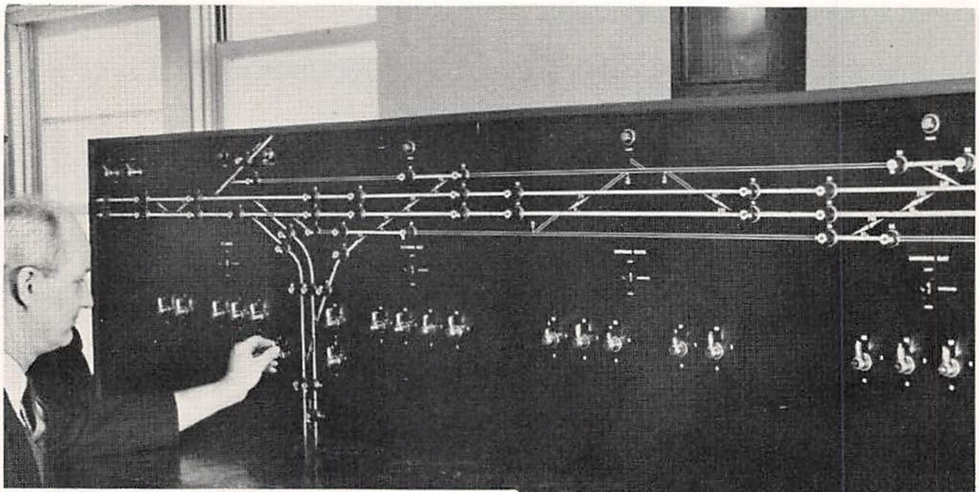


Figure 34. Relay interlocking control machine on Canadian National.

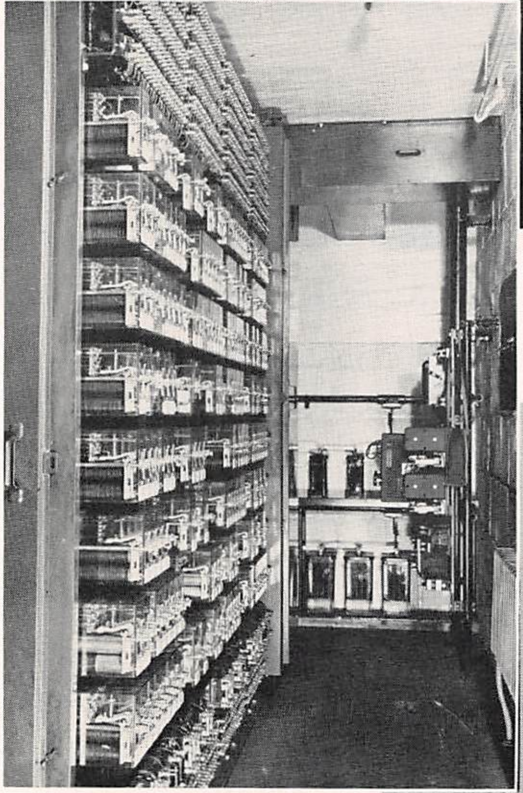


Figure 35. Type B plug-in relays on Canadian National.

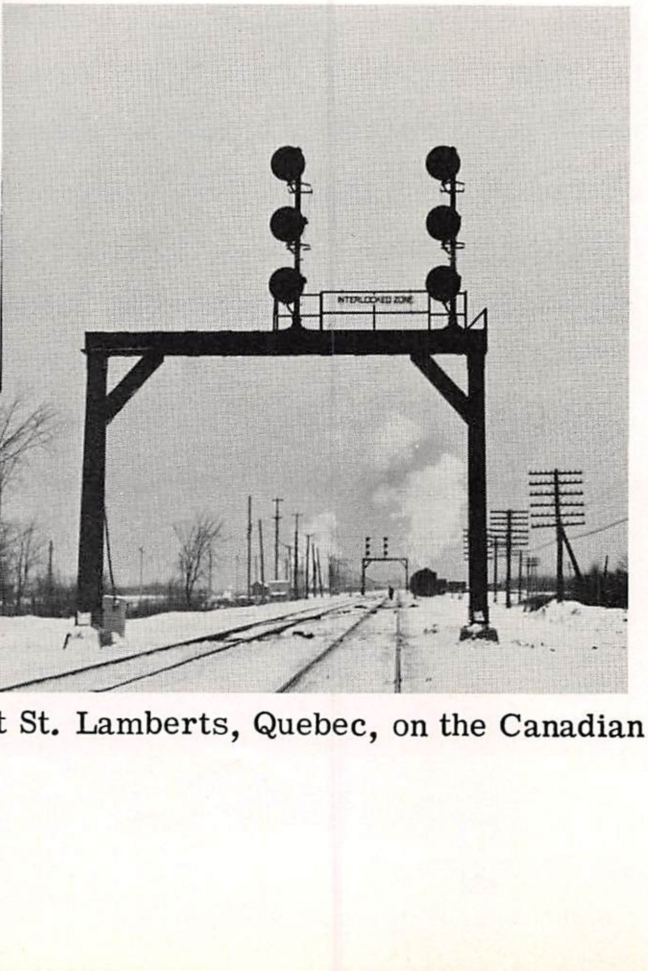


Figure 36. Relay interlocking at St. Lamberts, Quebec, on the Canadian National.

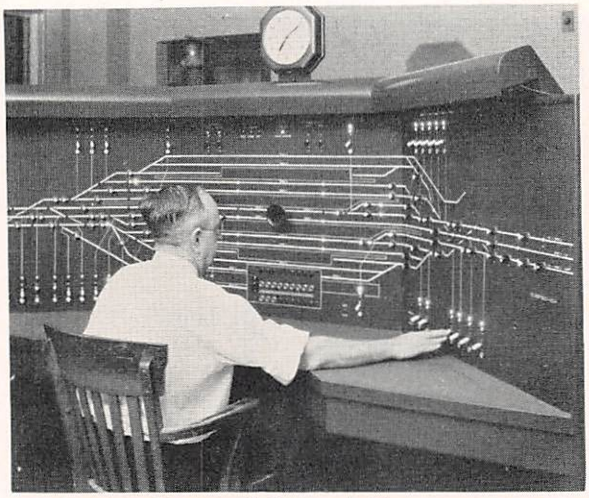
- Lower operating and maintenance costs - mechanical fitting is dispensed with, as are electromechanical lever locks.
- Smaller control machines need smaller towers, with resultant lower installation and annual operating and maintenance costs. In fact, for many installations the control machines may be located in existing stations or towers along with other facilities.
- Existing switches, signals, electric locks, etc., may be reused.
- Future changes can be made with greater ease than with older forms of interlocking.

The General Railway Signal Company's control machines for relay interlockings are available, as shown in Figure 37, in two types; the Type B, which rests on a table or desk, or the Type C, which stands on the floor. The Type B may be of sectional construction. The Type C may be equipped with a shelf or desk, with or without drawers. Other features, such as space for telegraph and telephone instruments or other facilities,may be provided as required.

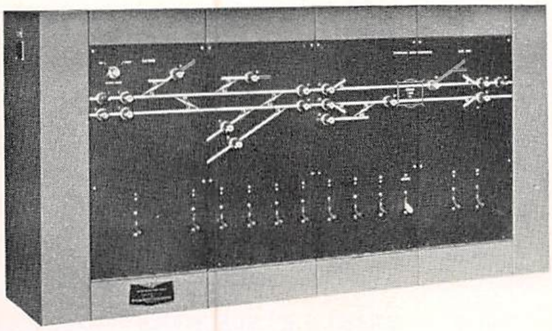
These machines use a laminated black and white phenolic plate for control panels, with a black satin finish. All track markings, signal numbers and other data are engraved on the panel, the engravings cutting through the black satin finish surface to the underlying white lamination. In this way, markings are distinct, neat, and permanent.

Control panels are made up of one or more large panels or may be made up in standardized sections, each section 10 inches wide and as high as required. With the sectional panels, future changes or additions may be made without disturbing the entire machine.

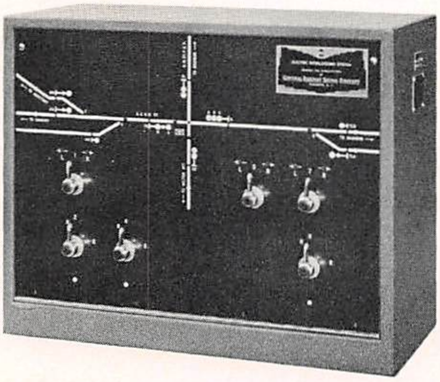
Access to the switches, lamps, terminals, etc. may be either from the back or by means of hinged control panels on the Type B machines. In Type C machines, access is from the back by means of removable or hinged covers.



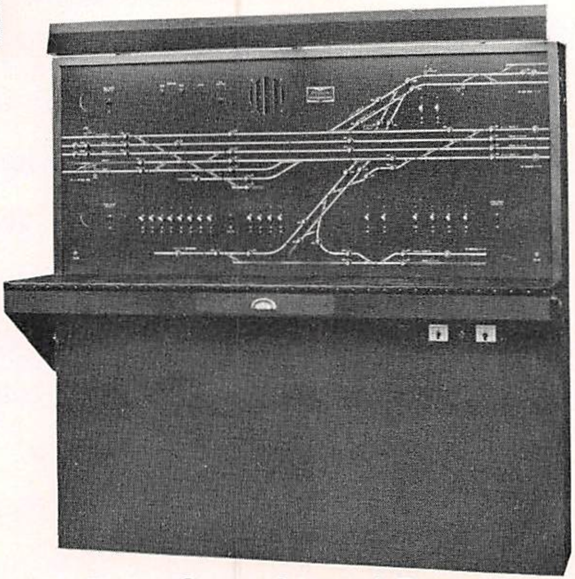
Type C machine at Syracuse, New York, on the New York Central System.



Type B machine at Madison, Wisconsin, on the Chicago and Northwestern.



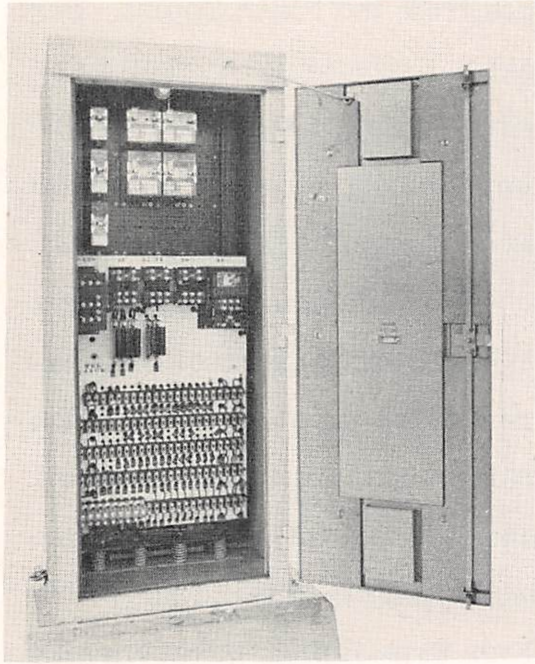
Type B machine at Philadelphia, Pennsylvania, on the Baltimore and Ohio.



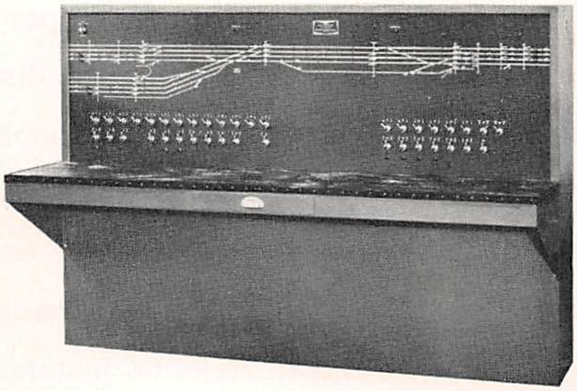
Type C machine at Depew, New York, on the New York Central System.

Figure 37. Relay interlocking control machines.

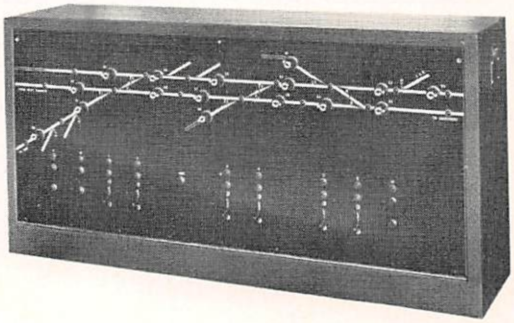
The control panels are engraved to represent the approximate geographic arrangement of the track layout. Indications giving operating information on the panel may be displayed entirely by lights (white or colored) or by the movable point indicator system. With this system, small movable point indicators, electro-magnetically operated, are mounted in the control panel at switch point locations. These movable points, black in color, are flush with the panel front. They pivot across the



Relay and terminal housing on the Canadian National.



Type C machine at New Rochelle, New York, on the New York, New Haven and Hartford.



Type B machine at Leaside, Ontario, on the Canadian Pacific.

white track lines at the point of divergence to show a solid white line for the route set up. They may be circuited to follow the lever movement or the switch movement. Signal-clear, switch out of correspondence, switch lock, track occupancy and any other indications are displayed by lamps carried either in the barrels of the levers or knobs or in sockets carried by the panel itself and located adjacent to the levers or in the engraved track diagram. Most such indication lamps are circuited to be normally dark. Audible signals, such as a one-stroke bell, are usually used to attract the operator's attention when a train is approaching.

The number of relays required per switch and signal varies according to the layout being signaled and distance from the control point. For near groups it is usually more economical to use simpler circuits and more wires from the control office to the functions. If the functions are remotely located, it is usually more economical to develop circuits which keep wire requirements to a minimum even though such circuits may require more relays. In some instances, coding equipment employing a 2-wire line circuit, similar to that used in coded traffic control installations, is employed to control a number of remotely located functions. Such coding equipment is made up chiefly of relays which may be the small G-R-S Type A quick detachable plug-in type. These relays are also often used for the non-vital circuits (such as indication circuits) in unit-wire or non-coded installations. G-R-S Type K or Type B plug-in relays may be used for the so-called vital circuits, the operation of which affects the safety of train operation.

Some circuits must be varied according to whether Type K or B relays are used. The present trend is toward the use of Type B relays because their greater contact capacity and variety of available operating characteristics make for simpler circuits, less wiring, and less space. The quick detachable feature of these relays is a decided asset in busy interlockers, as replacements or changeouts for inspection and tests can be made with little interference to operation.

G-R-S Models 5C or D switch machines are especially recommended for use in relay interlocking, the 5D wherever the dual-control feature is desired for the convenience of trainmen operating the switch by hand, such as when switching at a remote location. Both models may be relay controlled and use relayed battery indication. G-R-S Type SA (searchlight) color-light signals are widely used in relay interlocking, both for high and dwarf signals. G-R-S Types MD and ME color-light dwarf signals are also widely used where only two indications are desired. G-R-S Model 10 electric switch locks may be used to provide electric lock protection for hand-operated switches. As previously stated, any existing switch machines, signals, or other functions may be reused, but it is, of course, recommended that due consideration be given as to whether there is real economy in reusing old equipment, especially when future operating and maintenance costs must be considered.

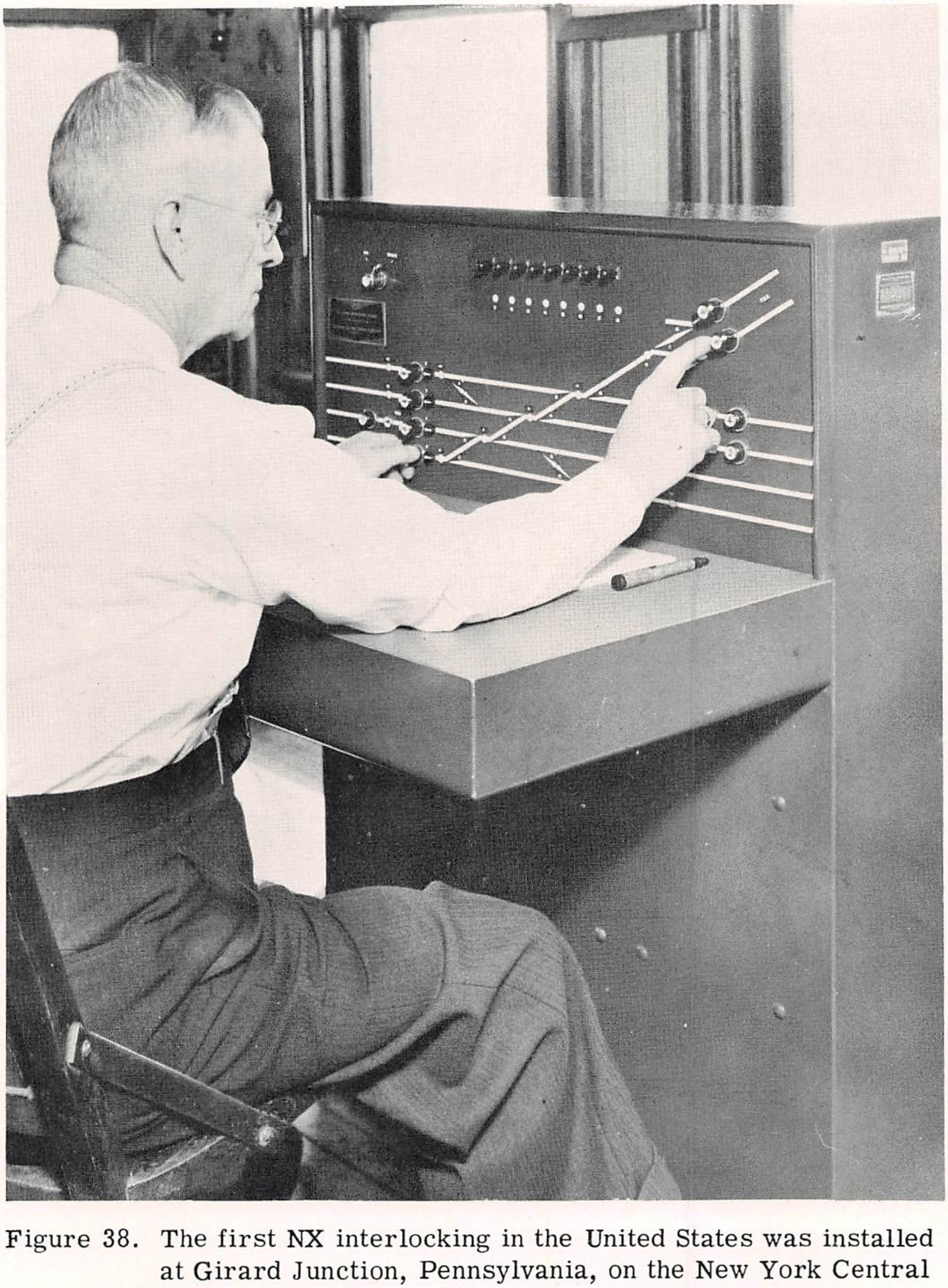


Figure 38. The first NX interlocking in the United States was installed at Girard Junction, Pennsylvania, on the New York Central System. Existing switches and signals were reused.

NX INTERLOCKING

The General Railway Signal Company's NX system of electric interlocking bears a marked resemblance to the relay system of electric interlocking. The important departure, however, is the method of setting up routes, that is, the method employed for controlling the individual switches and signals. The NX method reduces the setting up of routes to the fundamentals of recognizing where a train is entering the plant, and identifying the point where it is to leave the plant.

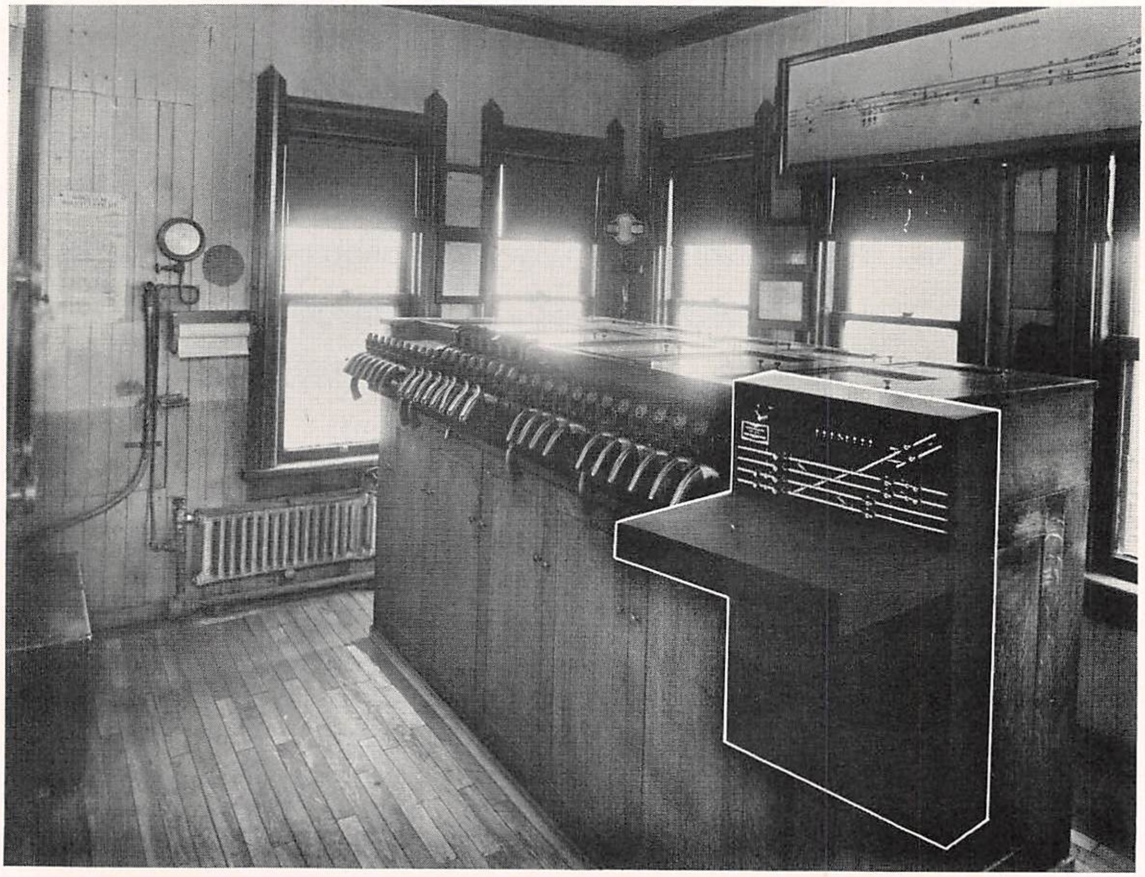
The objectives of the system are:

1. To simplify the directing of trains.
2. To speed up operations.
3. To minimize the possibility of error in routing trains.

The basic idea behind NX was that a route has an entrance and an exit. The term NX was coined by the General Railway Signal Company from the first syllables of the words en-trance - ex-it = en - ex. On a miniature track diagram, there is an entrance knob at every possible entrance; and an exit button at every exit. The entrance knobs are physically represented by interlocking signals on the ground.

Control Machines

Control machines are built in two general types, the floor (Type C) and the table top (Type B). The floor type, Figure 38, has a desk 30 or 40 inches above floor level, depending on whether the operator is to sit or stand at the machine. The table top type, Figure 43, page 74, is recommended where the room is small and the machine can be installed on the operator's table or in a niche in a wall.



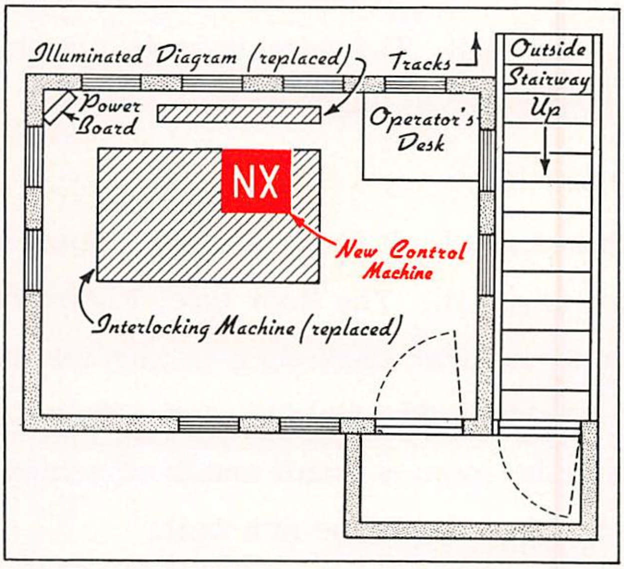

Illuminated Diagram (replaced)
Tracks
Outside Stairway
Up
Power Board
Operator's Desk
NX
New Control Machine
Interlocking Machine (replaced)

Figure 39. Note how this NX machine compares in size to the old electric interlocking machine it replaced. The existing switches and signals were not disturbed.

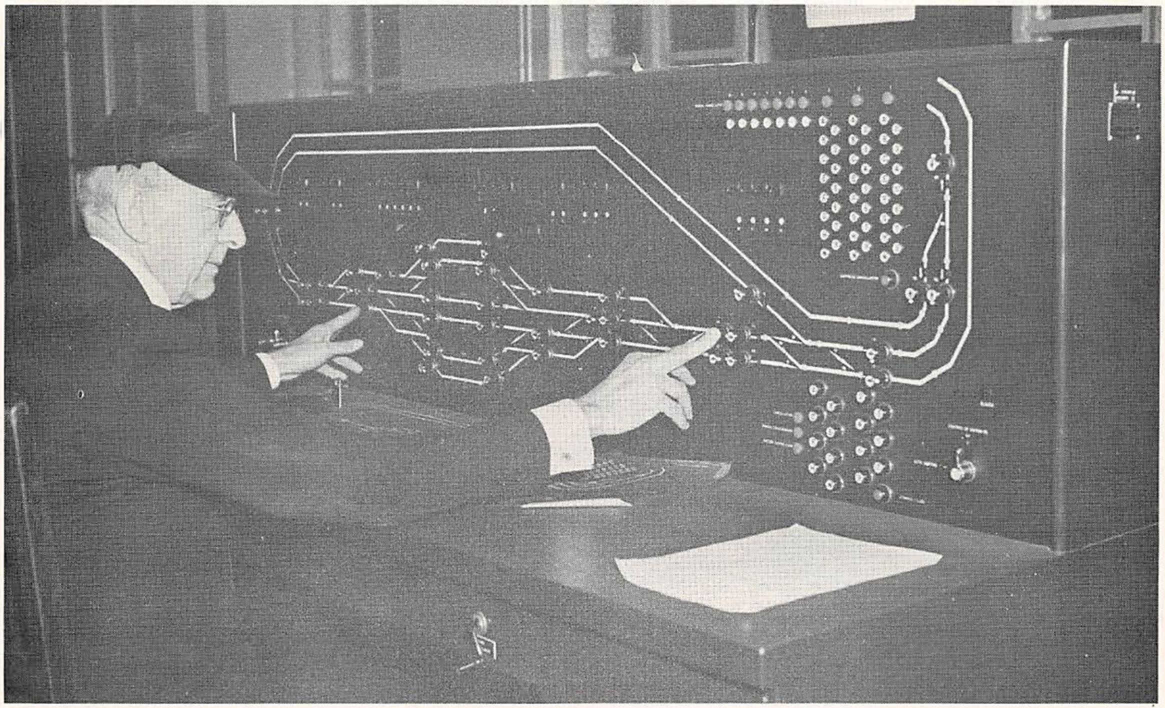


Figure 40. This NX machine was designed to handle over 1000 train movements daily and has handled as high as 32 trains during a 20-minute rush period at San Francisco, California.

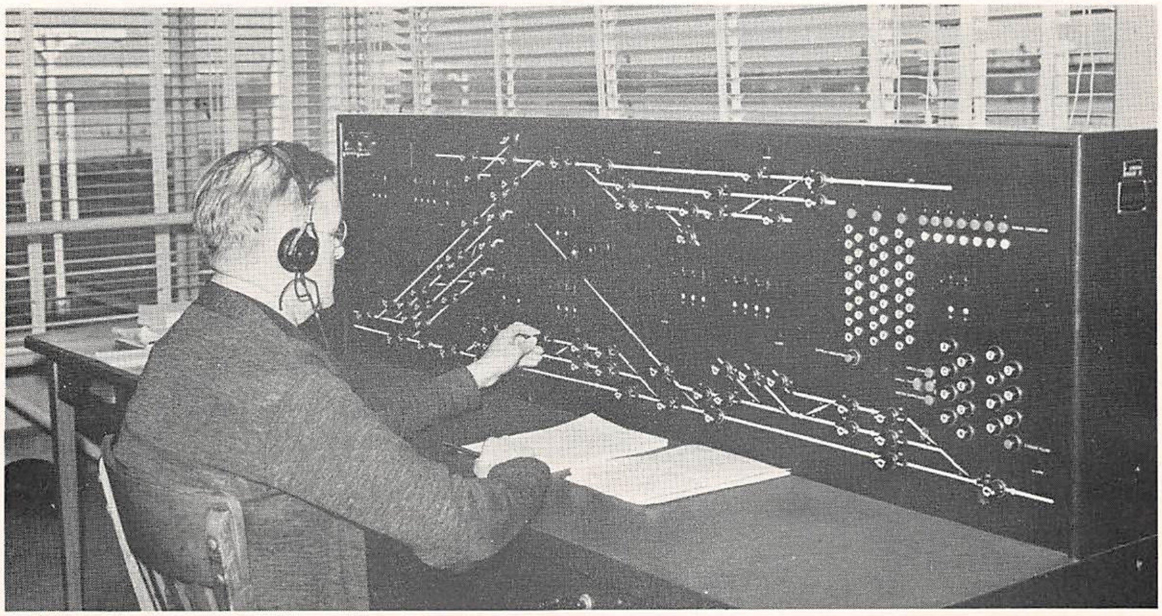


Figure 41. This machine was made to control a coach yard at Oakland, California, for adding or removing cars from trains to meet varying traffic demands. It has handled over 1000 trains daily plus 1500 switching moves.

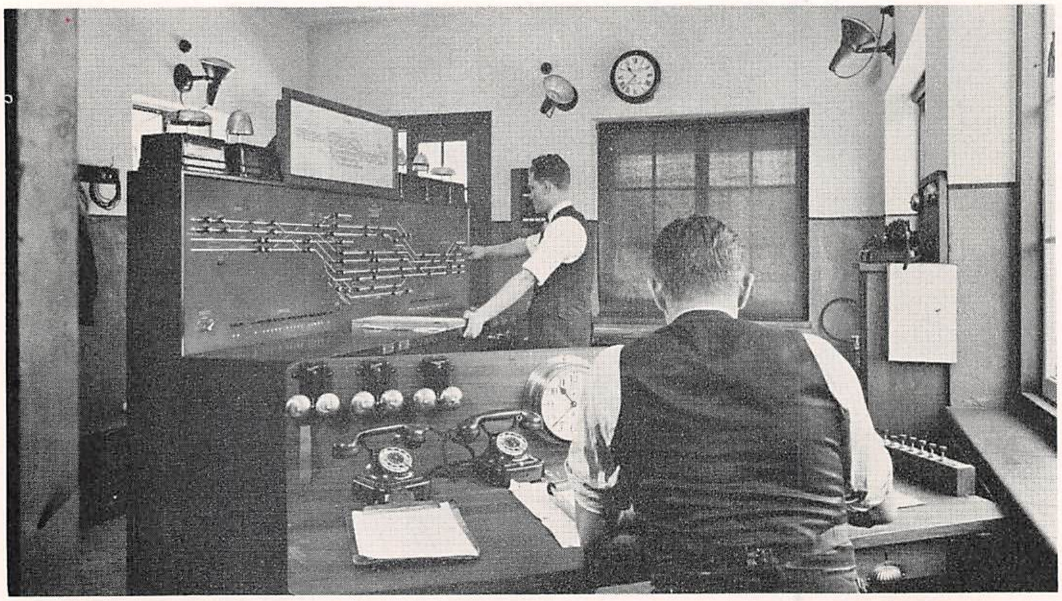


Figure 42. A large installation went in service in 1939 in Johannesburg, South Africa. The Joburg machine handles dense interurban electric traffic, some 500 to 600 trains daily. Over 1000 routes are lined up daily.

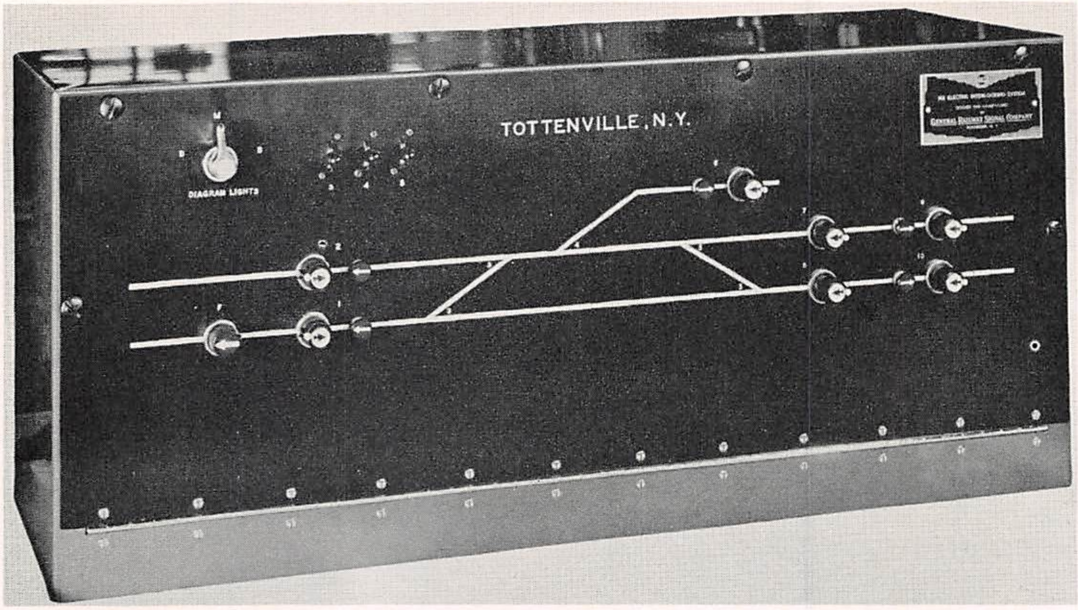

TOTTENVILLE, N.Y.
DIAGRAM LIGHTS
GENERAL RAILWAY SIGNAL COMPANY

Figure 43. The first NX line-o-lite installation was placed in service in 1940 at Tottenville, N. Y., on the Staten Island Rapid Transit. Routes lined up are shown by a series of strips of white light which changes to red when the train is present.

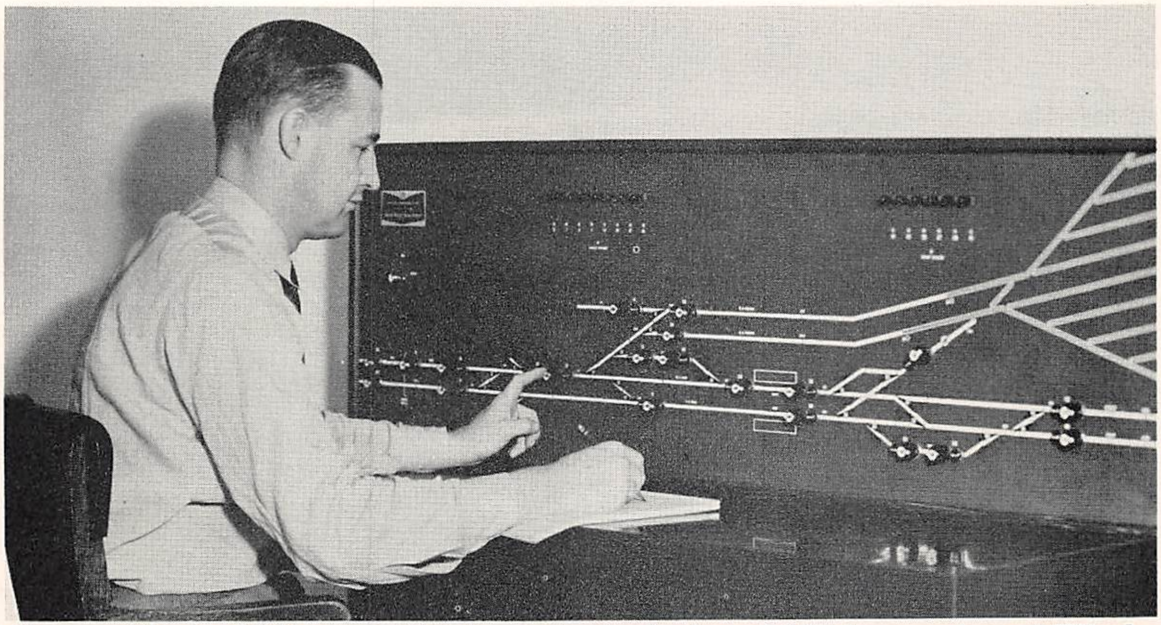


Figure 44. In 1940, the Michigan Central placed NX in service at Windsor, Ontario, the first installation in Canada. At Windsor, steam locomotives uncouple, and electric locomotives draw trains into Detroit through the tunnel under the Detroit river. This machine, handling 74 trains daily and numerous switching moves, was installed in the passenger station. Two interlocking towers were eliminated, and existing switches and signals were used.

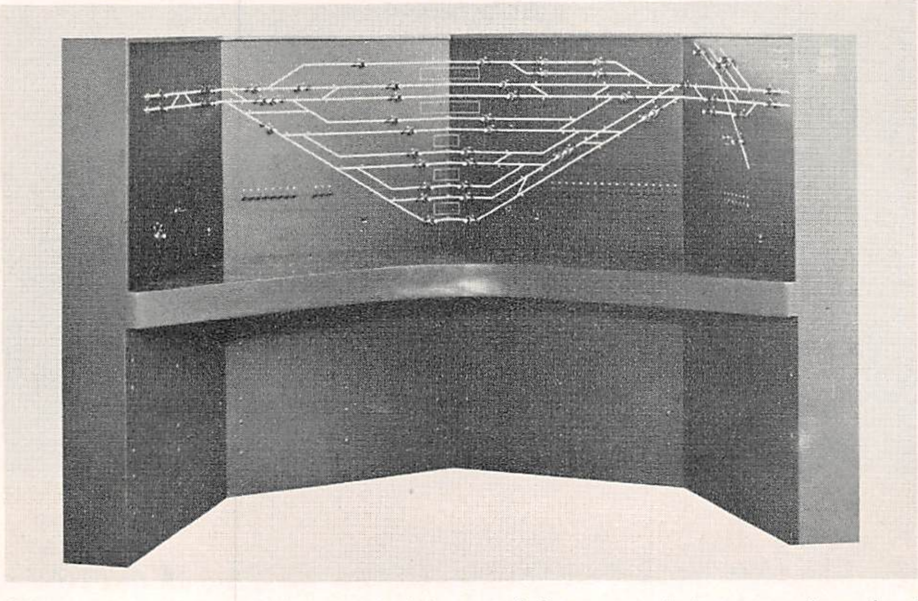
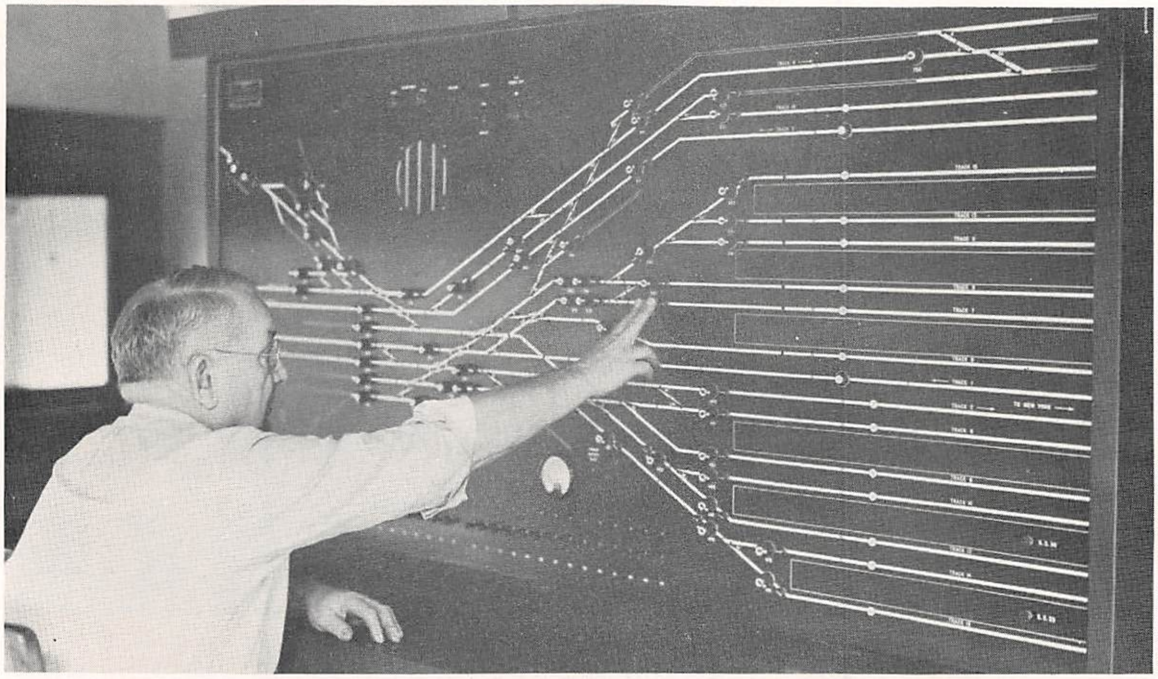


Figure 45. A large point-of-light machine went in service in 1943 at Birmingham Terminal, Alabama. Birmingham sets up 400 to 600 routes daily.



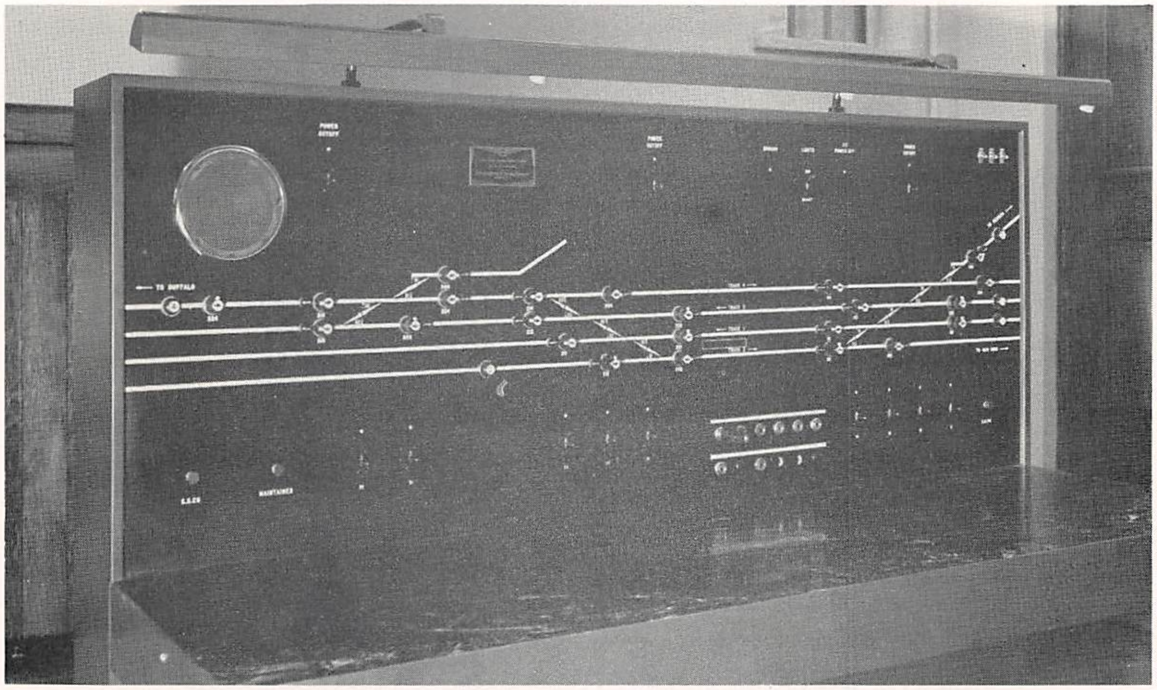


Figure 46. The New York Central placed two NX jobs in service in 1943, one at Utica (top) and one at Herkimer (bottom). Utica NX replaced a 224-lever electric interlocking machine. Handles 400 movements per day.

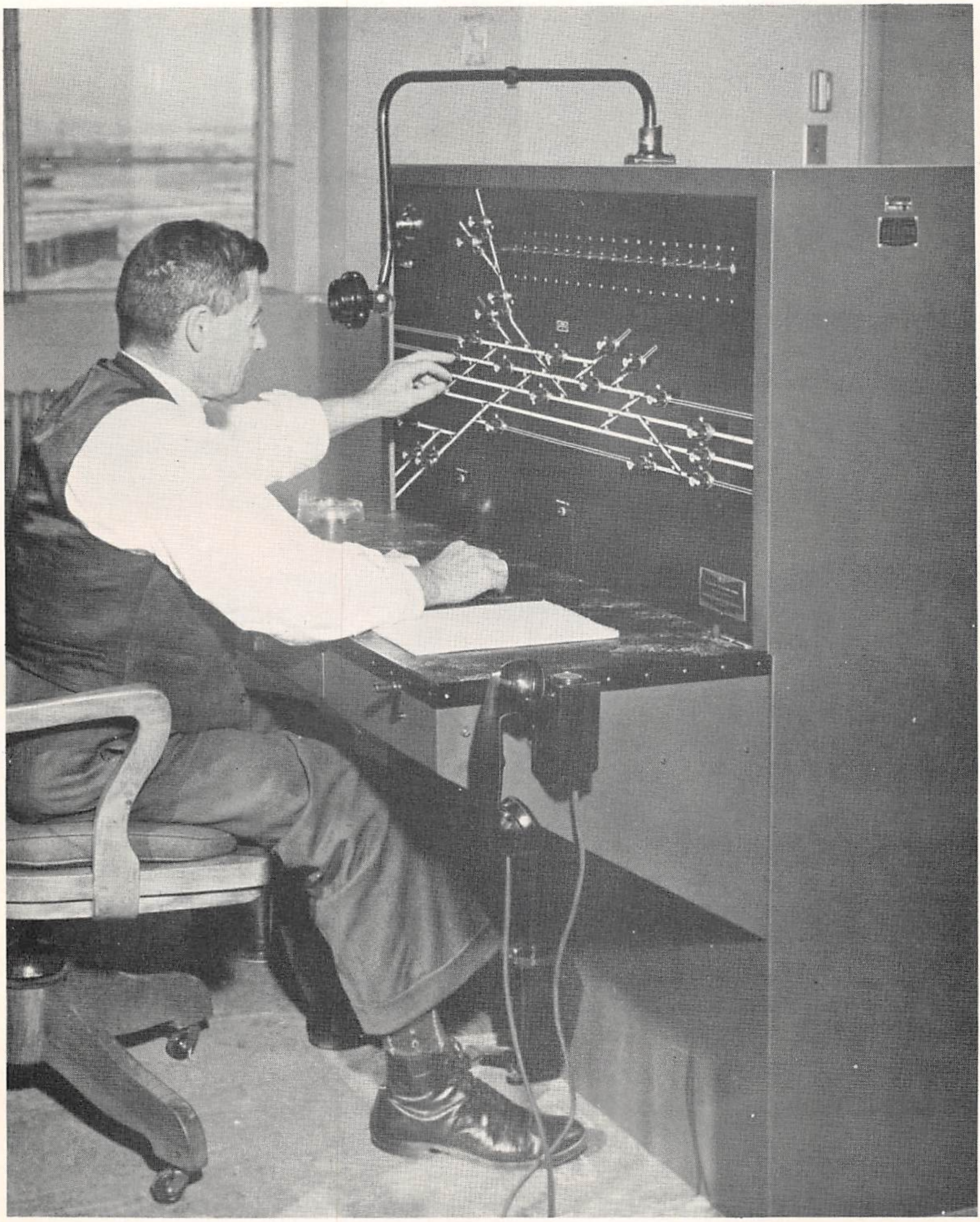
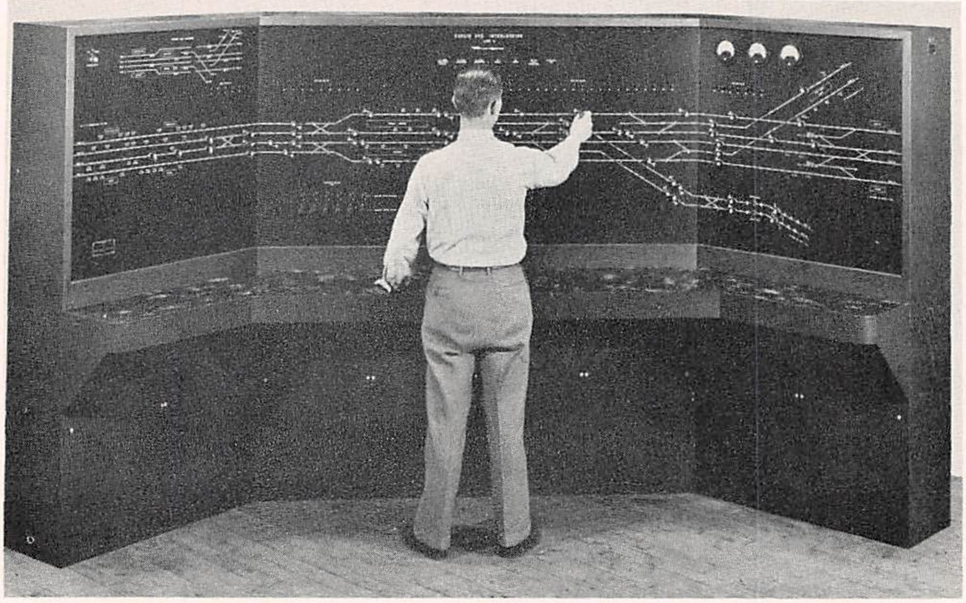


Figure 47. The Canadian Pacific put in a large job at Rugby Junction (Winnipeg), Manitoba in 1947, handling 68 through trains and 400 switching moves daily.



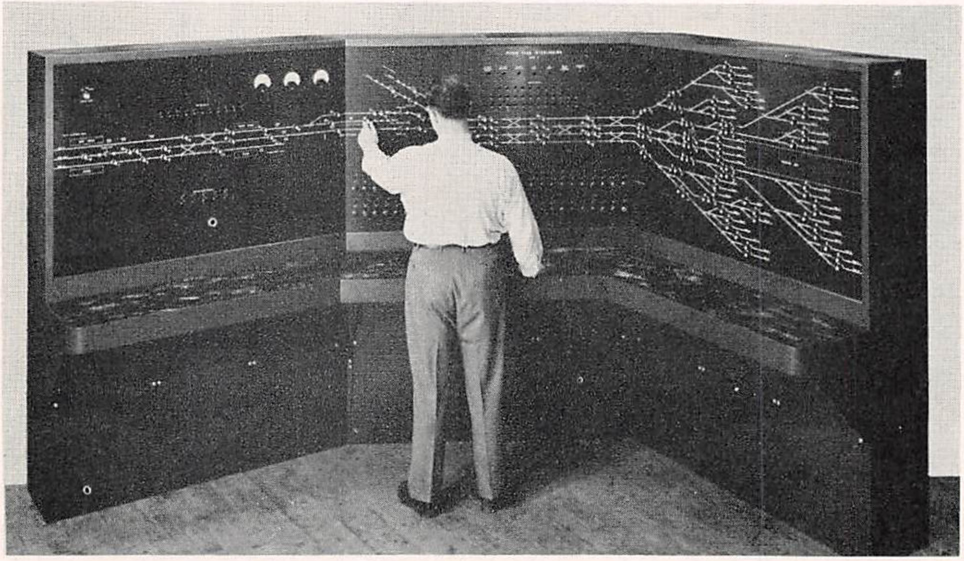


Figure 48. The New York City Board of Transportation installed two NX jobs in East Brooklyn, one at Euclid Ave. (top) and one at Pitkin Yard (bottom) in 1949. These machines can handle trains on a 90-second headway with 30-second station stops at local platforms and 45-second station stops at express platforms. The average operating speed for the signal layouts is taken at 20 miles per hour for rush-hour operation. Pitkin Yard is a very large installation with 76 switches and 164 controlled signals.

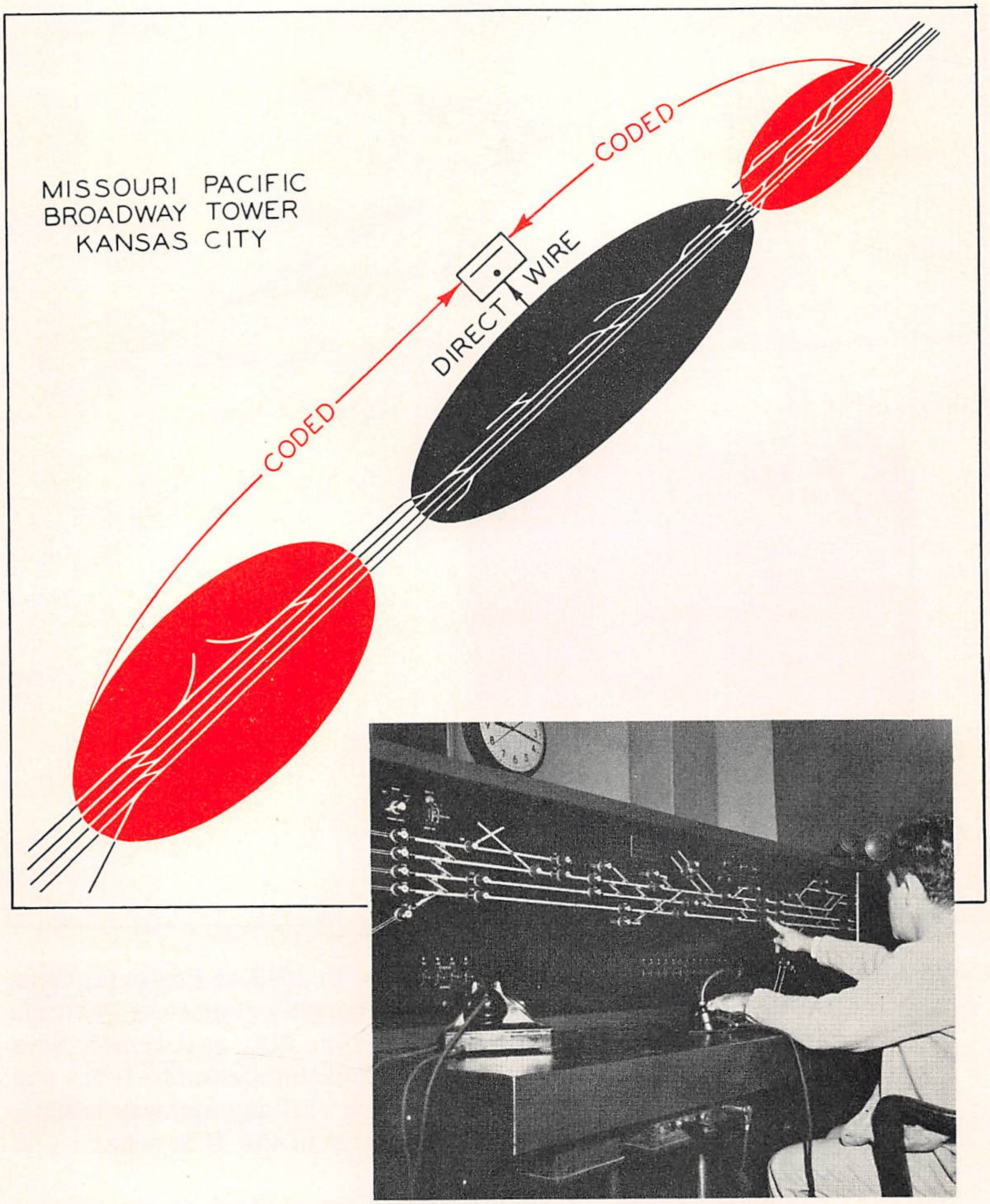

MISSOURI PACIFIC
BROADWAY TOWER
KANSAS CITY
CODED
DIRECT WIRE
CODED

Figure 49. Kansas City, Mo., on the Missouri Pacific was the first NX job where coded circuits were used to handle the controls and indications between Broadway Tower and two remote layouts. It went in service in 1949 and handles 800 train moves daily.

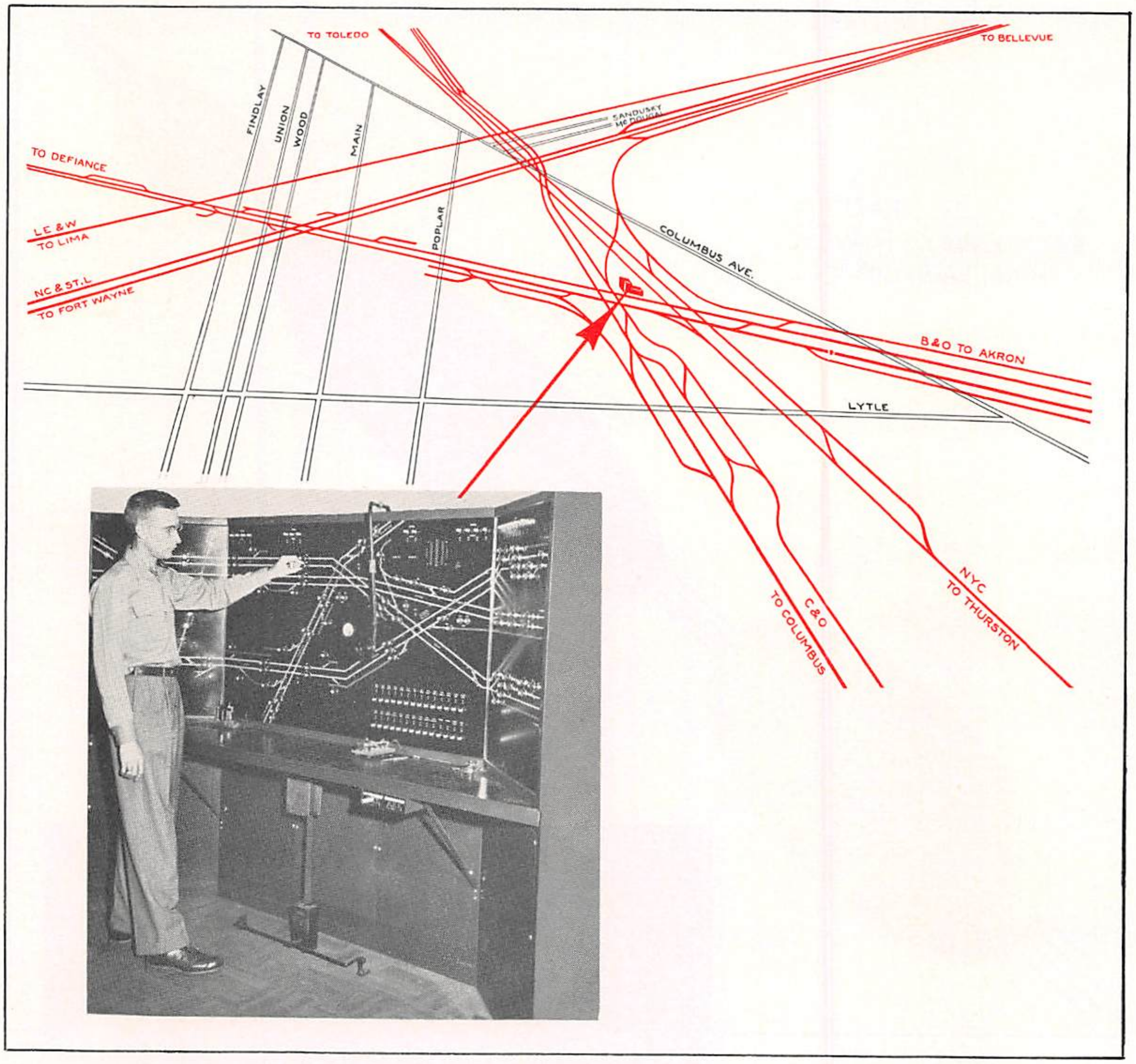

TO TOLEDO
TO BELLEVUE
FINDLAY
UNION
WOOD
MAIN
SANDUSKY
McDOUGAL
TO DEFIANCE
LE &W
TO LIMA
NC & ST.L
TO FORT WAYNE
POPLAR
COLUMBUS AVE.
B&O TO AKRON
LYTLE
C&O
TO COLUMBUS
NYC
TO THURSTON

Figure 50. A very large NX job went in service in 1949 at Fostoria, Ohio, on the New York Central. Five railroads crisscross Fostoria and intersect busy highways. Before NX, rail traffic was directed by dispatchers at three locations remote from one another. Tie-ups occurred, snarling rail and highway traffic. Fostoria was one of the few places in the U.S. where you could see a triangle tie-up.

Today the entire area is under the control of one operator. There is very little interference between trains and scarcely any stops. Highways are blocked for much shorter periods, and then chiefly by the numerous switching moves. Through traffic daily is 32 passenger and 130 freight; 200 switching moves.

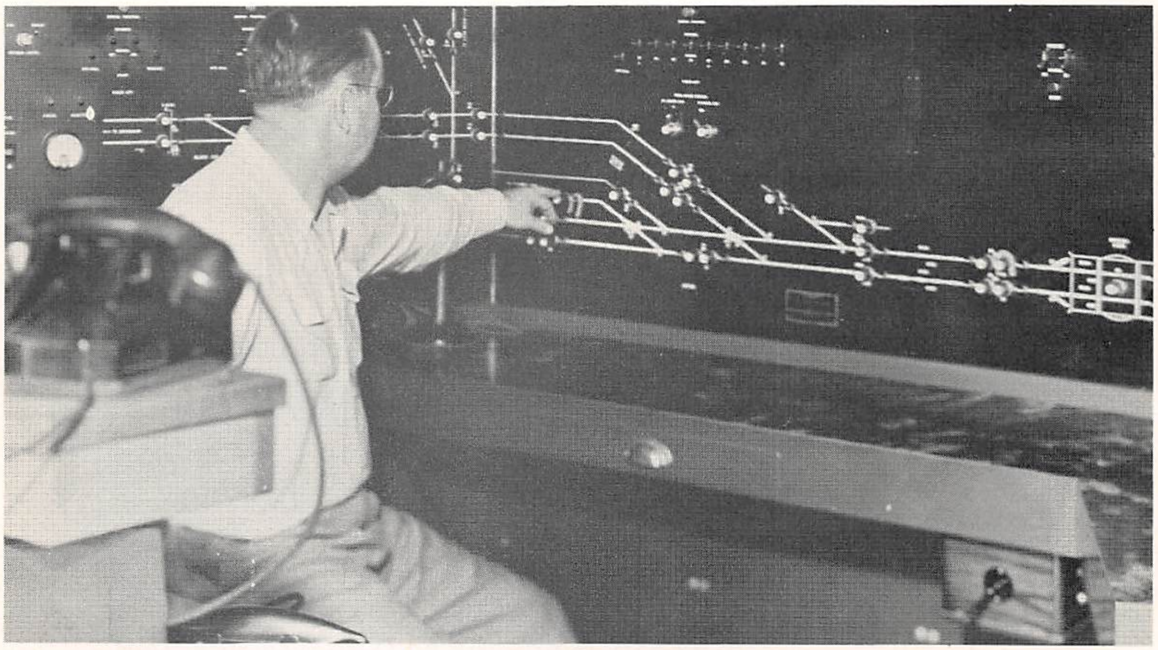


Figure 51. A large job has been placed in service on the CB&Q in Kansas City, consolidating two remote interlockings and eliminating one tower.

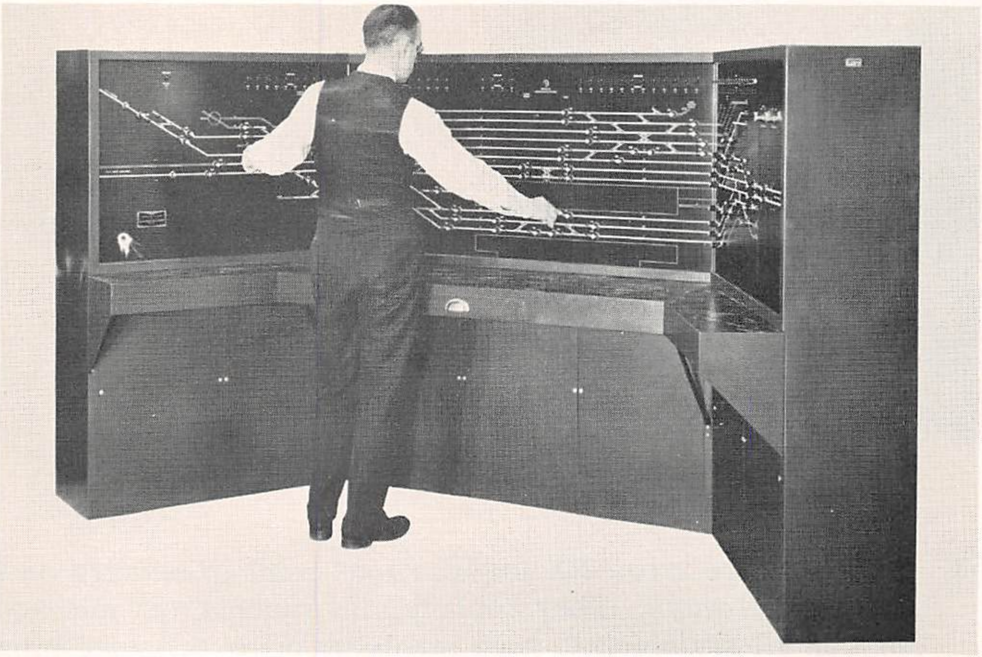
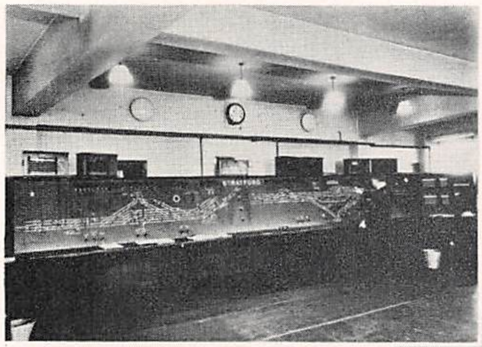
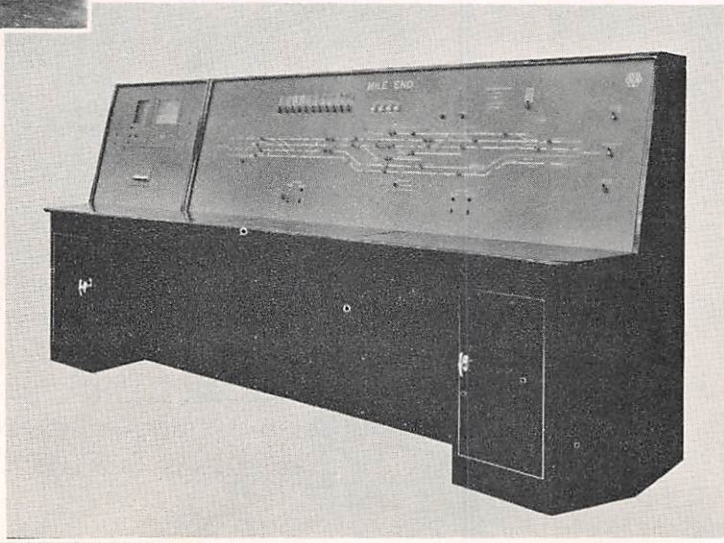


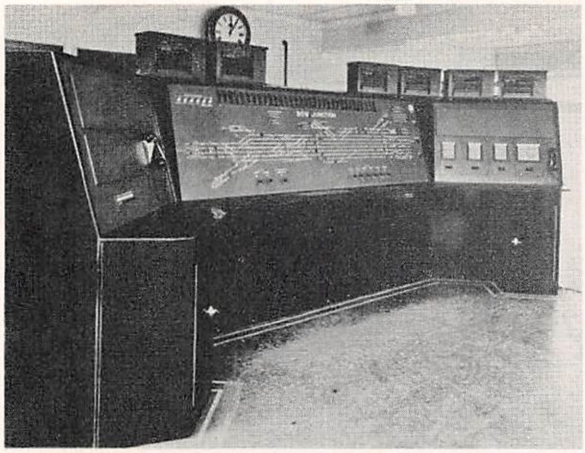
Figure 52. This machine at 's Hertogenbosch, on the Netherlands Railways, handles 170 trains and 1200 train movements daily.



The machine at Stratford has 178 routes.



The machine at Mile End has 42 routes.



The machine at Bow Junction has 64 routes.

Figure 53. In 1949 three large NX installations went in service on the British Railways. They replace nine mechanical interlockings on a busy electric road involving many crossing moves in extensive, complicated junctions. The signaling is designed to handle trains on a 90-second headway at speeds up to 75 miles per hour.

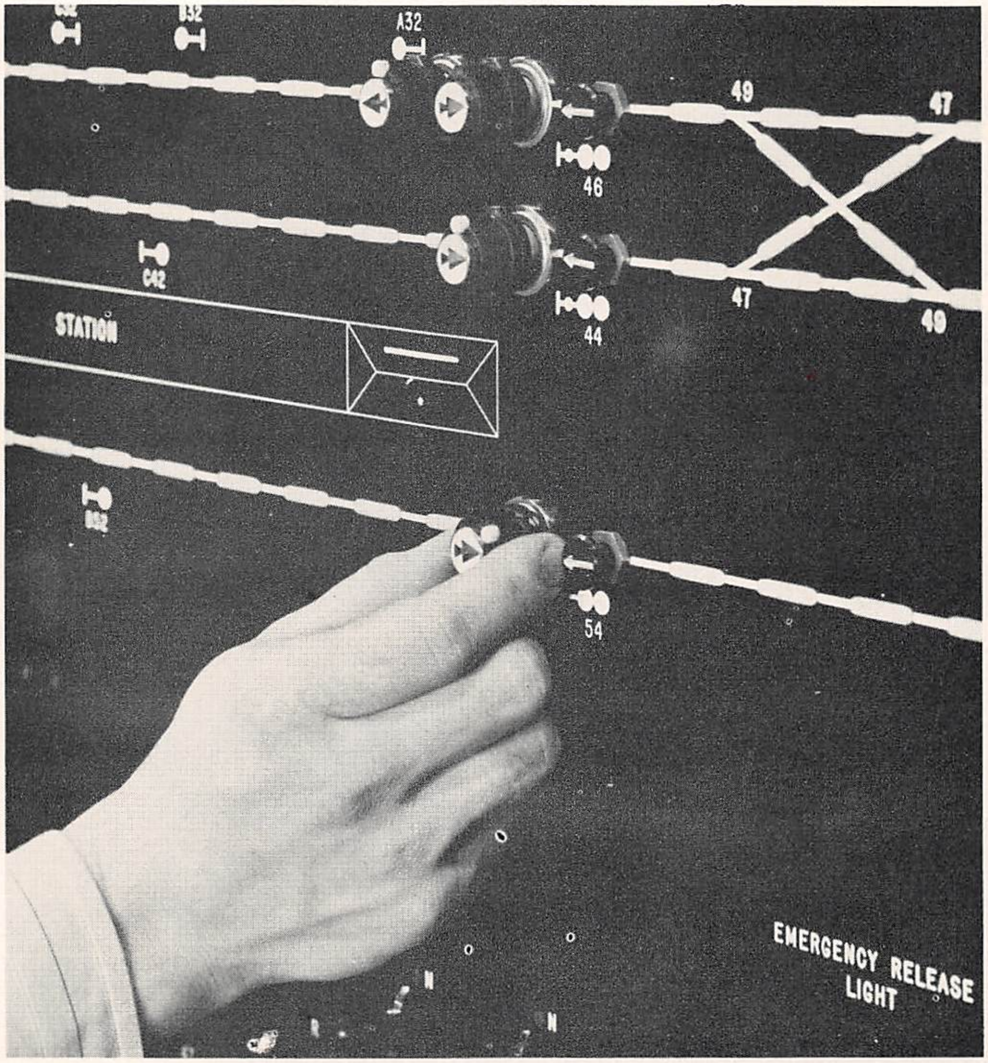


Figure 54. Close-up of NX panel, showing manipulation of entrance knob.

Entrance Knobs, Exit Buttons, Test Keys, and Indicators

Entrance knobs are located on the track diagram in the approximate geographical position of the signals they control. Arrows in the knob indicate the direction of traffic the signal governs. Lamps in the barrel of the knob indicate that the route has been initiated, or the signal is clear. Entrance knobs may be arranged for four manipulations; push, pull, turn up and turn down, or combinations thereof depending on the signal operation desired.

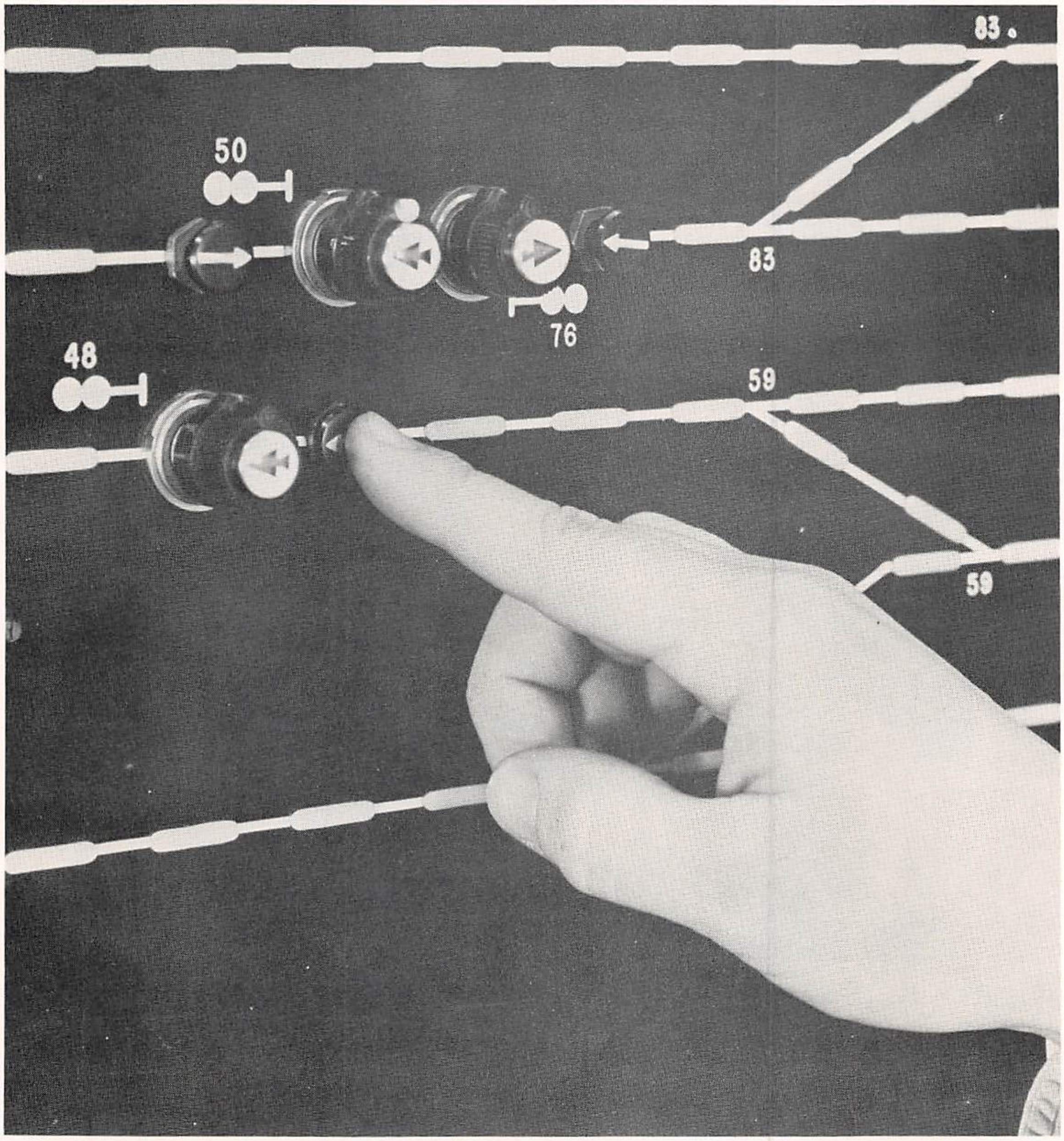


Figure 55. Close-up of NX panel, showing manipulation of exit button.

Exit buttons are located on the track diagram adjacent to the entrance knobs. Arrows indicate the direction of traffic for which they may be used. If desired, lights may be provided in the exit buttons, which, when a route lineup is initiated (by manipulation of an entrance knob), will light up and indicate to what exits routes are available at that time.

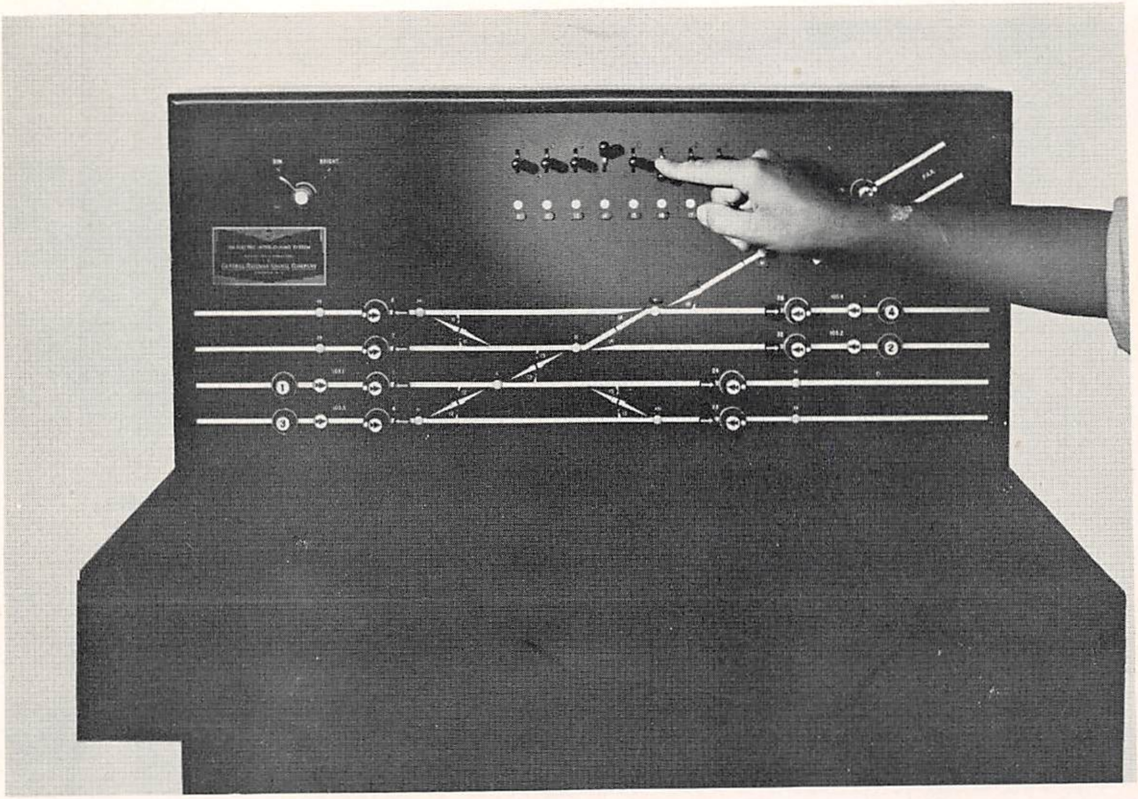


Figure 56. There is a test key for each switch.

Test keys, one for each switch, crossover, movable point frog or derail, are located in some convenient space on the control panel, above or below the track diagram, as desired. By means of them, switches may be operated individually whenever conditions permit or a switch may be held to one position, inoperative as far as NX operation is concerned, but signals governing movements over it in this position may be cleared. In this manner, an alternate route may be set up in lieu of a preferred route even though the preferred route may be available at the time.

Indications giving operating information may be displayed entirely by lights, the point-of-light or the line-of-light system; or the small movable point type of indicators may be used to indicate the route lined up,with lights providing other required indications, track occupancy, lock, signal-clear, and so on.

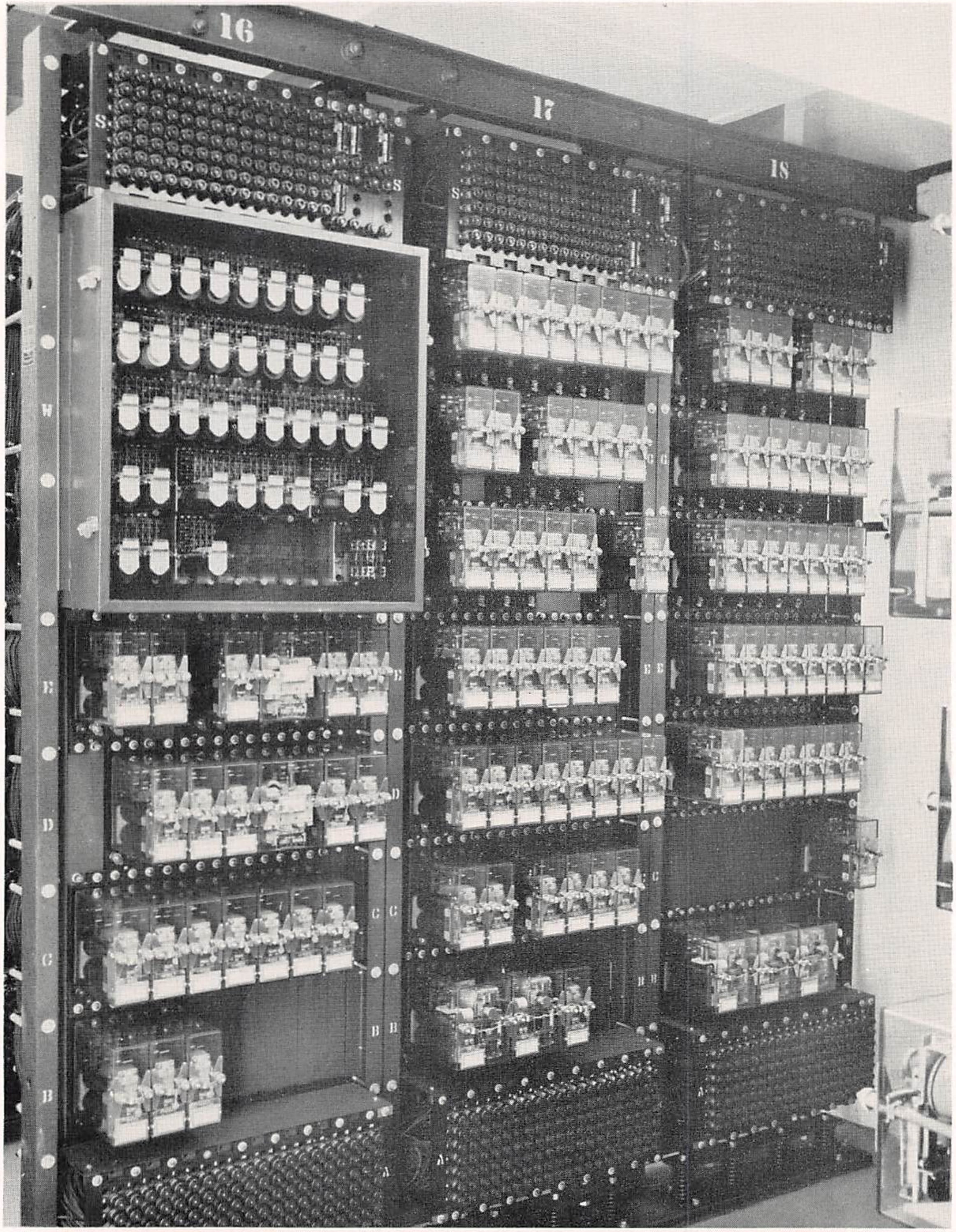

16
17
18
S
S
S
S
W
E
D
C
B
A

Figure 57. Type B plug-in relays in tower racks. Type A relays are in separate cabinet on left-hand rack.

Relays

G-R-S Type K relays may be used for all circuits in the NX system. Their exclusive use is recommended only for relatively small and simple installations with route indicator panels. They may advantageously be used with small cTc-type relays on any installation where the use of the Type B plug-in relay is not desired. Some modification of circuits and the sacrifice of certain features is necessary if Type K relays are used throughout.

Where space becomes a factor in an existing tower, Type B relays are recommended. They are small, compact, and have relatively greater contact capacity. They are all plugged in on plugboards mounted on racks 2 feet wide, which may be pre-wired in the factory and shipped in sections. A relay can be replaced in less than a minute.

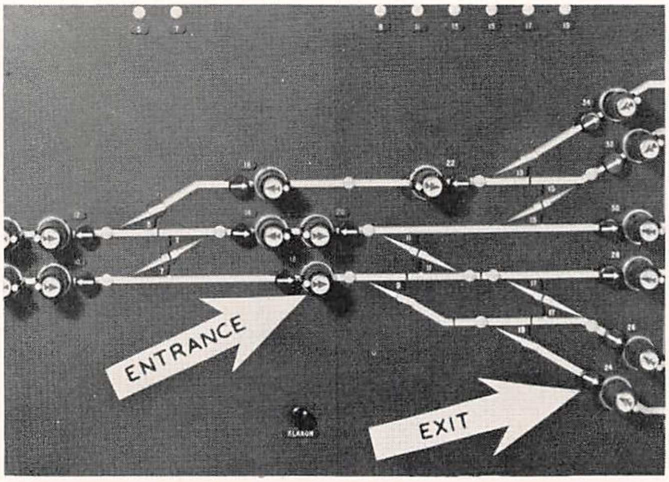
When economical to do so, non-vital circuits may be taken through small cTc-type plug-in relays which are housed in sheet-metal cabinets mounted on vertical pipes. These relays, called Type A, must be used with line-o-lite indications to avoid any undesirable light flashes.

NX Operation

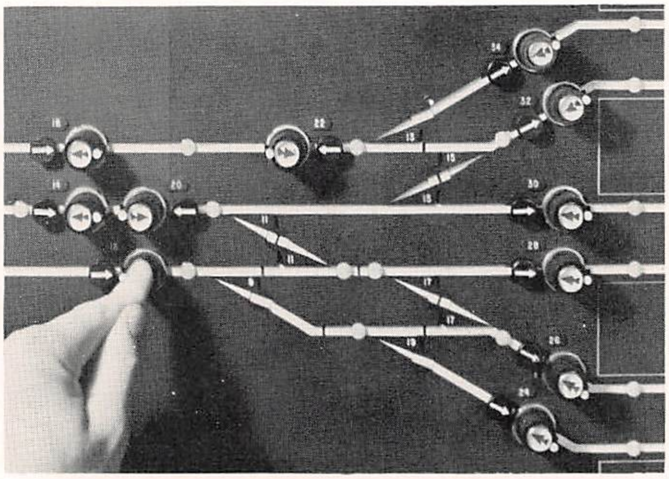
Let us now turn our attention to the actual NX operation starting with a simple route line-up.

A Simple Route Line-up

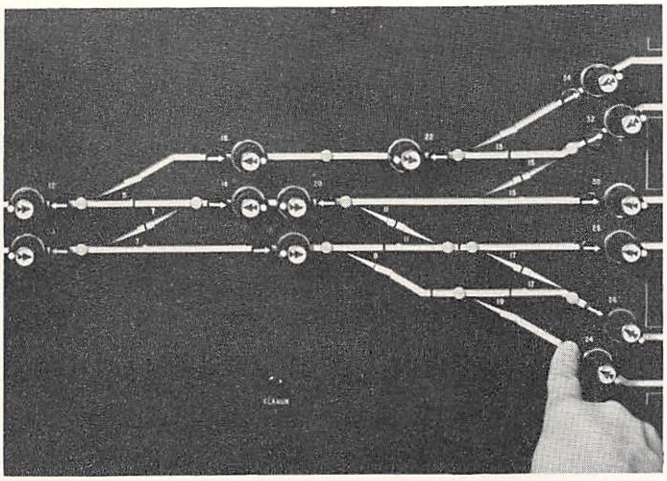
The following sequence of illustrations shows how the operator lines up a simple route between two opposing signals. The control panel used for these illustrations is the San Francisco installation, shown in Figure 40, page 73.



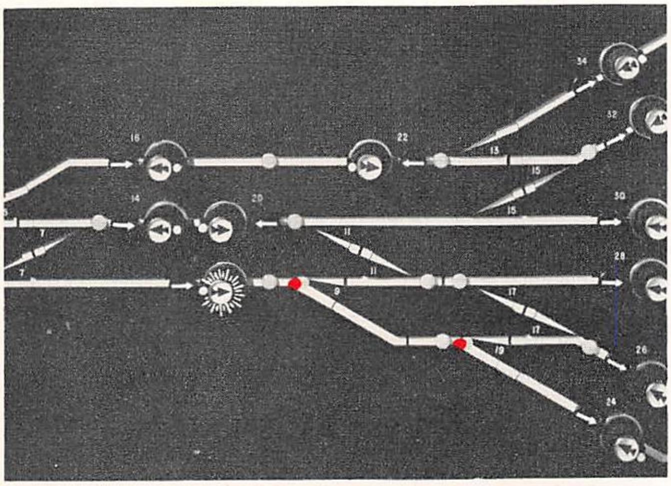
On this illustration we have added arrows to show the entrance and exit points of the route we wish to set up.



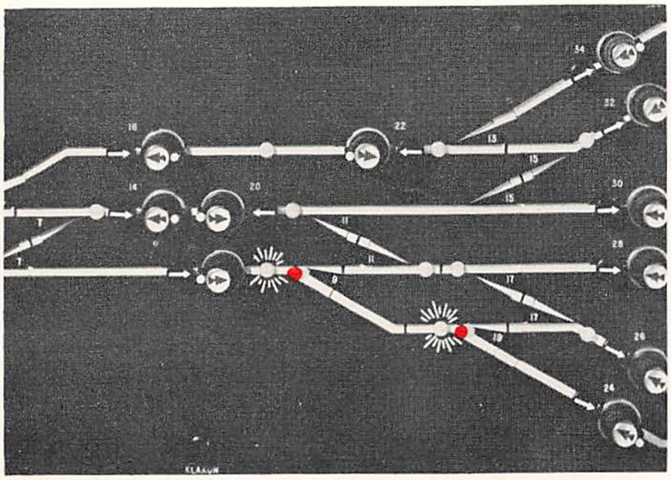
The operator presses the entrance knob corresponding with the point where the train will enter the route. The light behind the arrow begins to flash, indicating that a route has been initiated at that point.



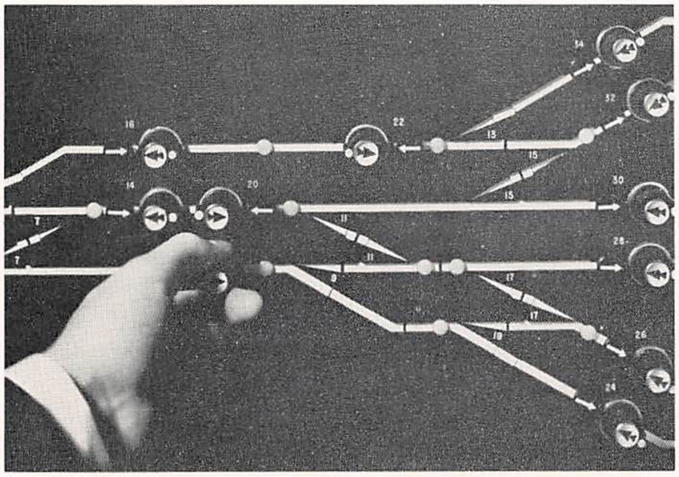
He next presses the exit button corresponding with the point where the train will leave the route. The rest is automatic. The entrance and exit points having once been established, the system throws the switches and clears the signals.



The route indicators snap into position to outline the route; red "lock lights," behind the pointed ends of the route indicators, show that the switches are locked; a steady white light in the entrance knob indicates that the signal has cleared.

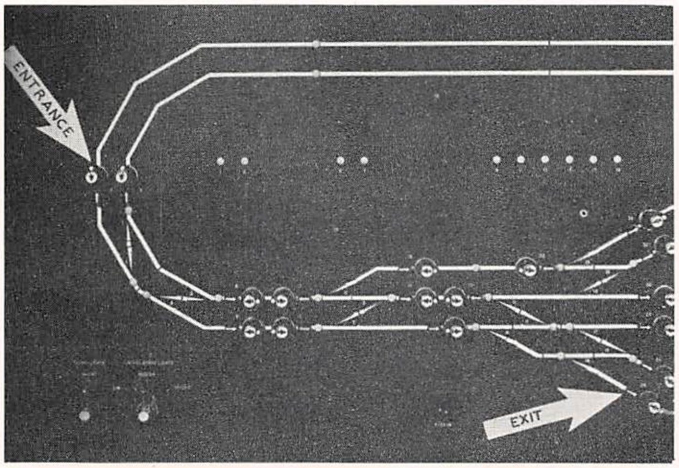


As the train travels over the route, the white track lights are illuminated. The light in the entrance knob is extinguished as the signal goes to stop behind the train. The red lock lights are extinguished as the switches in the route are released.

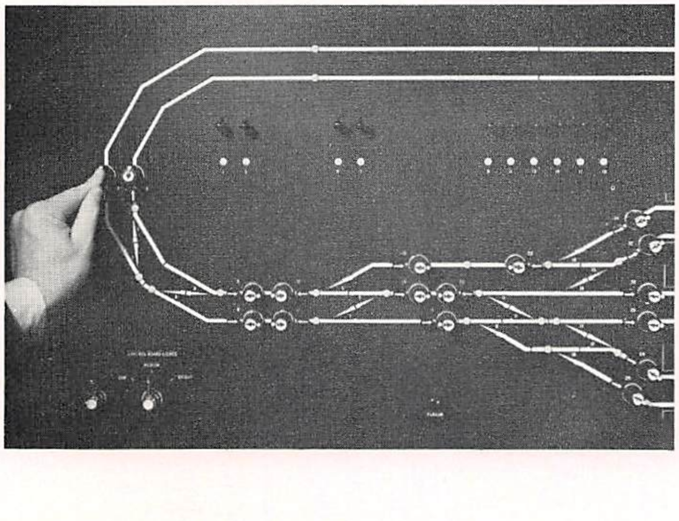


If the operator wishes to change the route before the train accepts it, he first cancels by pulling the entrance knob. He lines up the new route as described before.

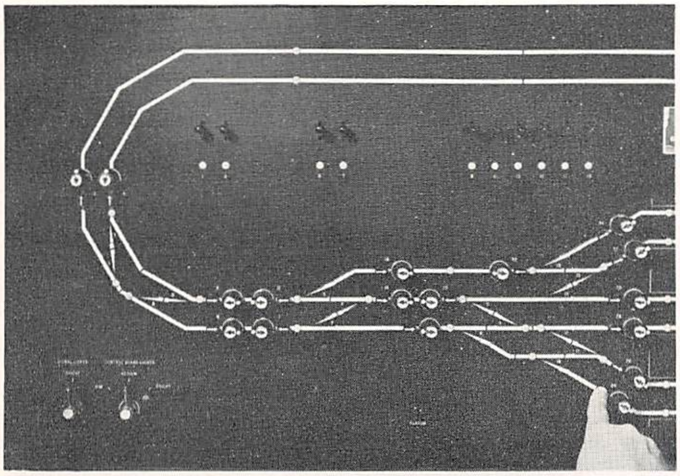
End-to-end Route Line-up



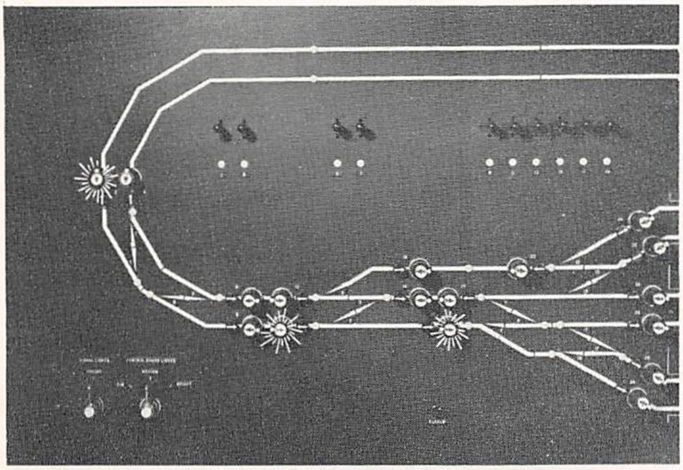
So far a simple short route line-up has been described. A long route comprising several sections could be lined up similarly from beginning to end by pressing each entrance knob and exit button having an arrow pointing in the same direction.



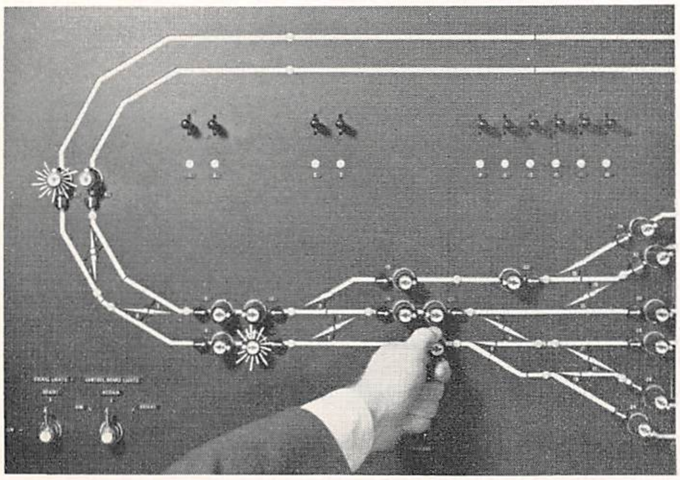
The end-to-end feature reduces this manipulation. The operator presses the entrance knob at the very beginning of the route.



He skips over the intervening buttons and presses the exit button at the very end of the route.



Route indicators line up, switches operate, signals clear (including the intermediate ones), and steady lights appear in the corresponding entrance knobs.

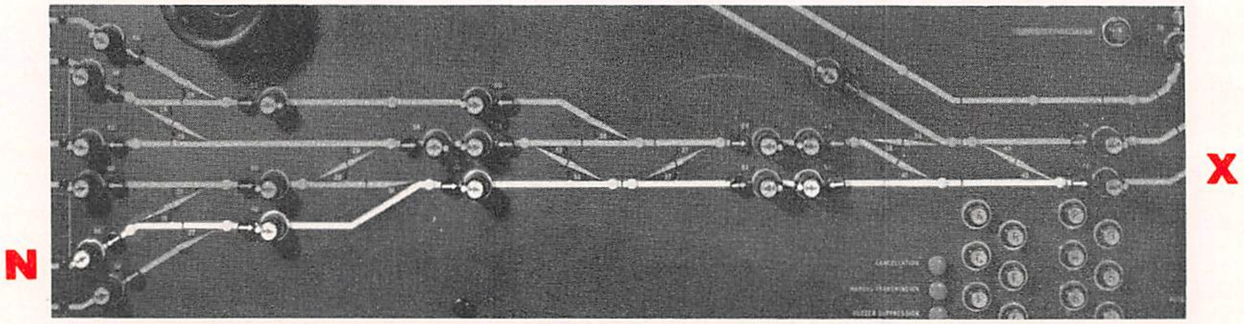


If the operator wishes to cancel any section of the route, he pulls the entrance knob. This puts the corresponding signal to stop and, if no train is approaching, releases the switches in that section.

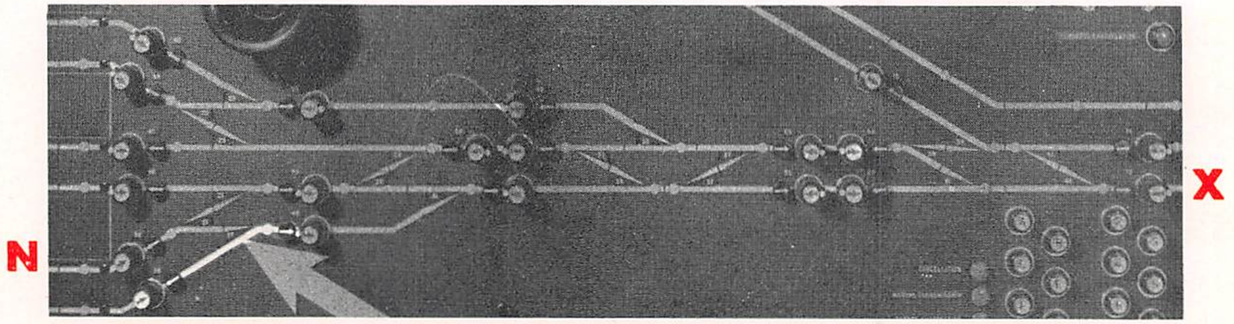
Automatic Route Selection

In a terminal or yard usually there are several routes between any two points. If one is obstructed, the operator can line up a second; but this takes time, as optional routes are usually more complex.

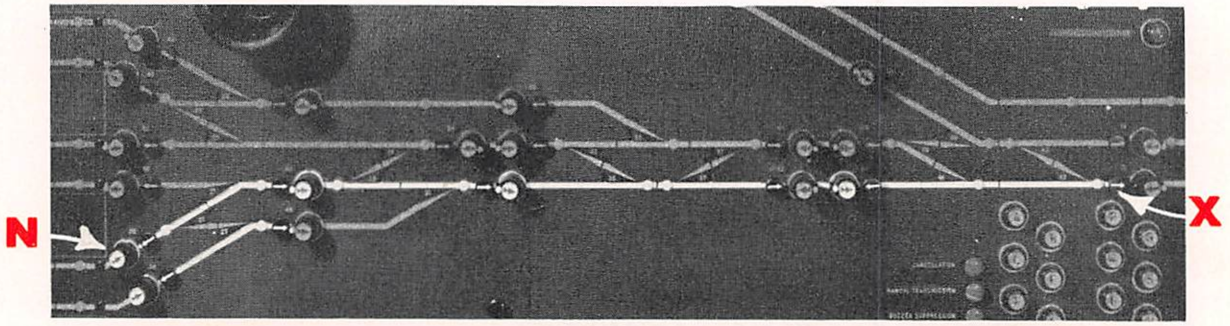
With NX, however, the operator presses the entrance knob and the exit button at the two ends of the route. If the preferred route is not available, the next best optional route is lined up instantly. The photo sequence tells the story.



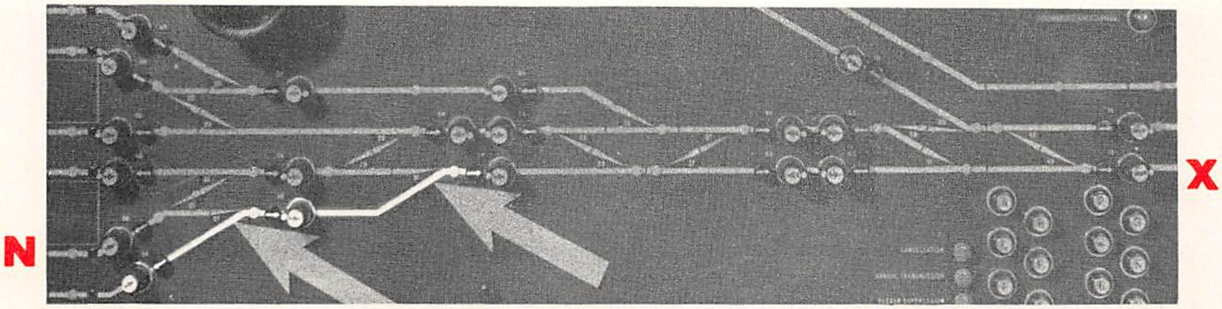
Here is the preferred route from an entrance N to an exit X.



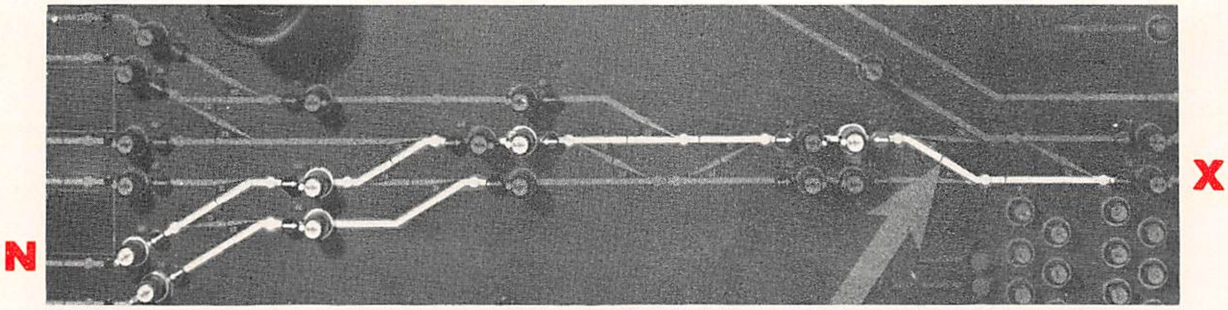
Suppose, however, that, before the operator lines up the route from N to X, the switch (marked by arrow) is used by the short route indicated.



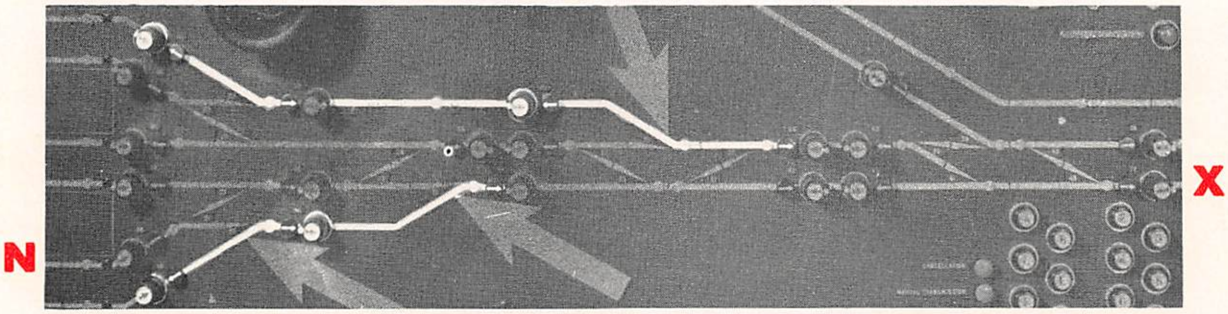
Now if the operator presses entrance knob N and exit button X, the NX system automatically lines up this next best route.



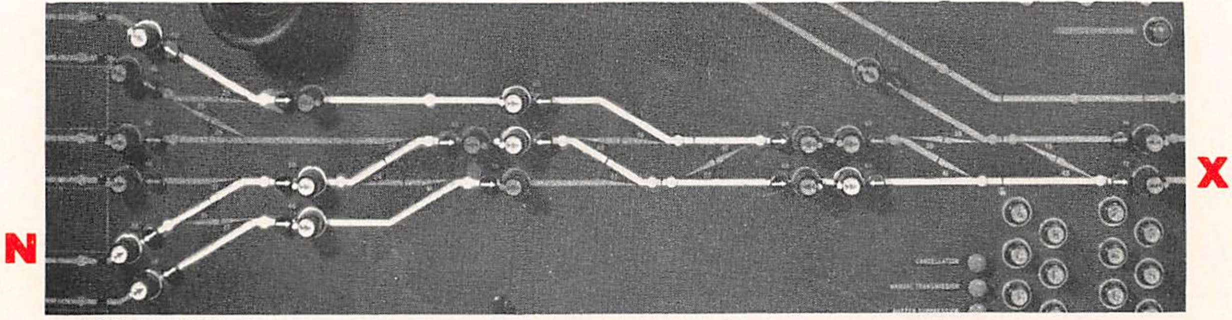
To go a step further, suppose that the two switches (pointed out by the arrows) are used by the short route indicated, and the operator still wishes to line up the route from N to X.



This is the new route from N to X. Note there are two possible crossovers that could have lined up, but the NX system chooses the one marked with an arrow because it is a high-speed crossover.



A third possibility exists in that the two routes indicated may be lined up. To select a route now from N to X would ordinarily take some mental effort on the part of the operator.



With NX, he again presses entrance knob N and exit button X; a route is immediately lined up.

NX Features

NX electric interlocking is equally adaptable to large or small layouts; however, the more complex the track arrangement and the more dense the traffic, the greater the advantage derived from the simplicity and speed of operation which distinguishes this system. Some NX features are:

1. Simplicity of operation:
   - (a) To line up any route, the operator merely manipulates an entrance knob and an exit button.
   - (b) The operator never has to think in terms of switches and signals. His sole concern is that of identifying routes by their ''entrances'' and ''exits''.
   - (c) If a preferred route is not available, an alternate route is automatically selected and set up.
   - (d) The control panel presents a geographic representation of the track layout. The operating picture is so clear on the control panel that no separate charts or diagrams are necessary.
   - (e) Individual switches, crossovers, etc., may be independently operated (when conditions permit) by means of test keys provided, one for each function.
   - (f) Any attempt to set up a conflicting route cannot disturb a route already established.
   - (g) Signals may be arranged to operate as desired: semi-automatic stick, semi-automatic non-stick, or non-automatic. Manner of operation may be selected by different manipulations of the entrance knobs.
2. Speed of operation:
   - (a) The operator makes only two simple movements to set up a route. This is true whether it be a simple route, an end-to-end

movement involving a number of switches and one or more intermediate signals, or the substitution of an alternate route if part of the preferred route is occupied or blocked. The time involved consists merely of the time required for the operator to make the two simple movements plus the time required for relays and switch machines and signals to operate - only a few seconds at the most.

(b) When routes are lined up with the automatic restoration feature, no levers or knobs need be restored to normal after the passage of a train.

(c) With the setting up of routes reduced to recognizing where a train is to enter the plant and identifying the point where it is to depart, the operator can give full attention to train operation, thereby speeding up the handling of traffic.

(d) Since one operator can handle many train movements, control of an entire terminal can often be concentrated under one man. This naturally makes for smoother and speedier operation.

3. Possibility of error reduced:

(a) With the operator having only to concentrate on the entrance point and exit point, the chances of setting up a wrong route are practically eliminated.

(b) Conflicting routes cannot be set up.

(c) The complete graphic picture of the track layout and the conditions existing largely eliminates the possibility of wrongly identifying the train, its entrance point or its exit point.

4. Maximum safety:

Accepted interlocking principles and practices, according to railroad standards, are combined in the NX electric interlocking system to insure maximum safety of operation.

5. Flexibility:
   - (a) NX can be applied to any form of power interlocking.
   - (b) NX can be applied to any track layout.
   - (c) NX can be arranged to provide any number of practical operating characteristics.
   - (d) NX circuits can be arranged for use with:
     - (1) G-R-S Type B plug-in relays throughout.
     - (2) G-R-S Type A plug-in relays for non-vital circuits and Type B relays for vital circuits.
     - (3) G-R-S Type A plug-in relays for non-vital circuits and G-R-S Type K relays for vital circuits.
   - (e) Panel indications may be varied to fit your preference.
   - (f) Floor or table-top type control machines can be furnished.

6. Economic:
   - (a) Smaller control room space is required. This permits using existing housing facilities; space in a station office for example, or smaller towers with a corresponding reduction in heating and maintenance requirements.

     If Type B plug-in relays are used, only about 1/3 the relay room space is required as when Type K relays are used.
   - (b) Control machine maintenance and replacement are less than that required for electric interlocking machines having mechanical locking between levers.
   - (c) One operator can handle large layouts with speed and efficiency.
   - (d) Operating benefits are derived from increased flexibility, speed and efficiency of operation.

REMOTE CONTROL

SECTION INDEX

General description and applications . . . 100

Unit-wire remote control. 101

Coded remote control 101

Factors determining choice of system . . . 102

Syncrostep coded system 103

GENERAL DESCRIPTION AND APPLICATIONS

Remote control is defined as a method of controlling and operating outlying signal apparatus from a designated point. Such apparatus, consisting of switches, signals, locks and other devices, is so interlocked that the setting up of conflicting routes or the clearing of signals that would permit a train to enter an unsafe route, or the taking away from a train of a route or a portion thereof into which the train has received a signal to enter, is prevented except as allowed by some predetermined procedure.

Remote control is used to advantage at ends of sidings or double track, crossovers, junction points, yard leads, crossings and similar layouts where an operator at some remote station or office can exercise the required manual control of power-operated switches and signals, which will enable trains to proceed without stopping or unduly slowing down. Trains can be directed by signal indications in such a manner that full advantage can be taken of conditions as they occur. Train movements are thus expedited; and safety, track capacity, and overall efficiency of operation are increased.

Remote control is frequently used to replace existing interlockers, particularly small interlockers in need of repair or replacement. Appreciable reductions in annual maintenance and operation costs are often realized on such replacements.

Early remote control installations, which began in the 1920's, frequently employed table interlockers, with or without mechanical locking between levers. As the trend toward all-relay interlocking began, it soon became apparent that the same principles and practices could be readily adapted to remote control. Many circuits were devised, generally with the purpose in mind of keeping a minimum number of line wires between the control office and the field location. The result is that today there are two schemes in general use, the unit-wire system and the coded system.

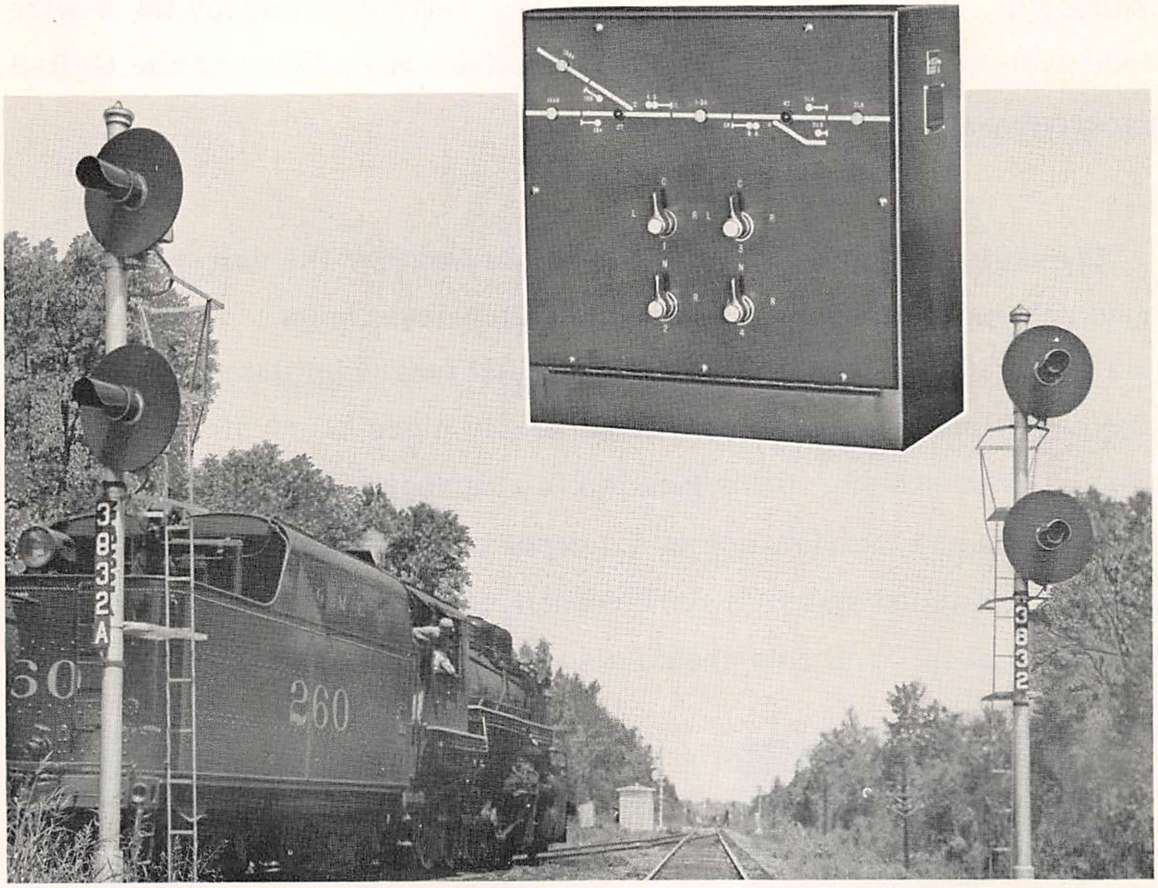


Figure 58. Unit-wire remote control on the Gulf, Mobile and Ohio.

UNIT-WIRE REMOTE CONTROL

The unit-wire system employs circuits that utilize each wire between the control office and the field location for more than one purpose, that is, one wire may transmit the switch control outward (from control office) and the signal-clear indications inward, and another wire may transmit the signal control outward and the switch-correspondence and track information inward.

CODED REMOTE CONTROL

The coded systems reduce the number of line wires between the control office and the field location to a bare minimum - two or three wires, depending on the code system used, for any number of field functions and indications. The almost universal practice today is to employ the 2-wire code system such as the G-R-S Type K (see page 128) and the G-R-S Syncrostep (page 103).

FACTORS DETERMINING CHOICE OF SYSTEM

The determining factor which governs whether the unit-wire or the code scheme is to be used is generally an economic one. If the location is comparatively local, say a few thousand feet from the control office, and conditions are suitable, it is generally more economical to employ the unit-wire system. If the location is a number of miles distant, or the installation and maintenance of a number of line wires would be too expensive, the coded system may be economically justified. Possible future extension of the facilities should also be given consideration. The code

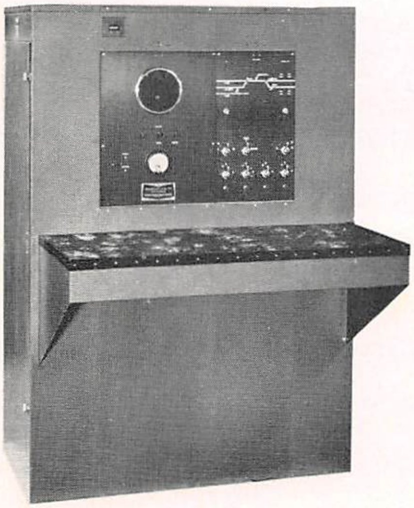


Figure 59. Coded remote control machine on the Southern Railway System.

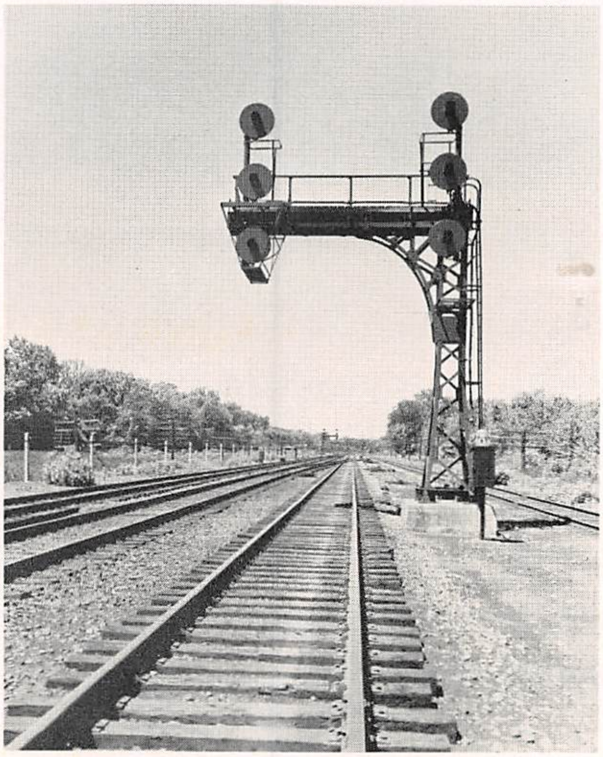


Figure 60. Remotely controlled Type SA signals on the New York Central System.

system can be extended at some later date to include additional locations at small additional cost. This would not be economically practical with the unit-wire scheme.

SYNCROSTEP CODED SYSTEM

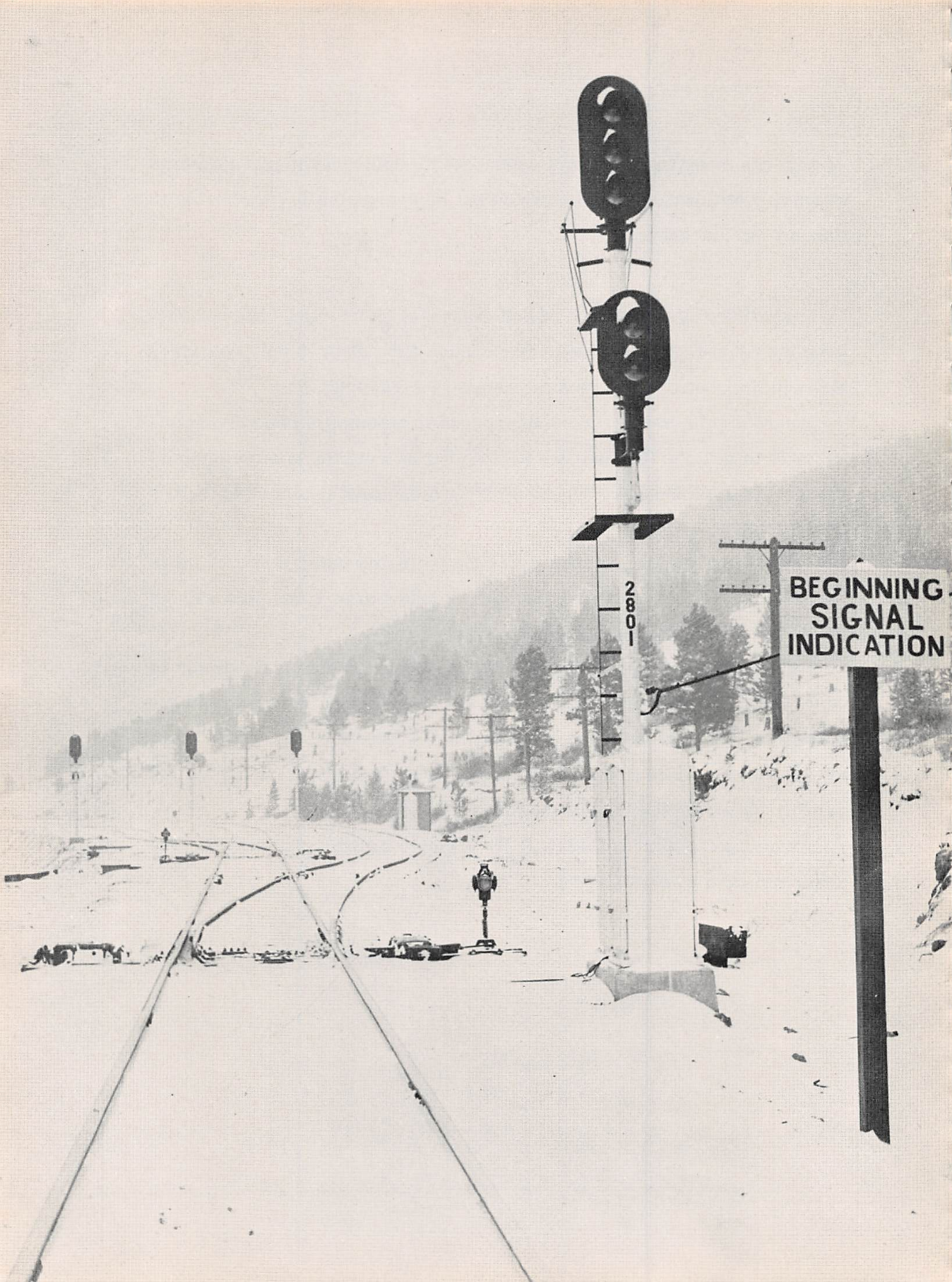
A new coded system for the remote control of interlockings has recently been introduced. It is known as Syncrostep, and requires only two wires between the control office and the remote interlocking.

Syncrostep is fast. It takes one second to transmit a control and two seconds to receive the indication. In other words, the control lever to reverse a switch is hardly flipped over when the switch points themselves start to move.

Syncrostep has large capacity for controls and indications. A large interlocking having many switches and signals can be controlled with as much ease as a small interlocking.

Syncrostep is easy to maintain. The operating principle is simple to understand. It is based on the unique principle of using free swings of two mechanical oscillators - one at each end of a two-wire line circuit - to create the steps of a code. The term Syncrostep is derived from the synchronous stepping thus produced.

For complete information on G-R-S remote control systems ask your nearest G-R-S representative.


2801
BEGINNING
SIGNAL
INDICATION

CENTRALIZED TRAFFIC CONTROL

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TRAIN OPERATION BEFORE cTc

In America, the common method of railroad operation has been - and still is on the greater mileage of roads - a method whereby the movements of trains over routes and through blocks are governed by means of time-table superiority and the use of train orders. These facilities may be supplemented by automatic block signals and by interlocking plants at strategic points. The train dispatcher is responsible for directing the movements of all trains over a section of tracks, usually an operating division of approximately one hundred or more miles of line made up of a succession of station-to-station blocks. In other countries, the basic method is somewhat different. Usually, trains are advanced station-to-station according to available time-space in the blocks and the ability of the stations at the receiving ends to accept the trains. Through trains are advanced by means of directions originating more or less at the scene of action, with some regard given to the schedules of time-table trains.

With the time-table and train-order method of operation, trains govern themselves to a large degree by means of their own schedules and the schedules of other trains. If a train is not scheduled, the dispatcher issues train orders which give it authority to occupy the main track and to govern its movements with respect to other trains. Such orders are transmitted to all trains concerned. If something happens which makes it necessary to revise a scheduled train's operation, additional orders must be issued accordingly. The dispatcher is dependent upon local wayside operators for information on the progress of trains, and he uses this information, along with his own knowledge of the road, the trains involved, the weather and other factors, to direct his trains intelligently. He is also dependent upon the wayside operators to get the orders to the respective train crews. This means the orders must be in the hands of the train crews prior to the time and place where the desired action is to be taken. The orders must be based upon operation predictions arrived at by studying all operating information available at the time the orders are originated. Any unpredicted operating situation happening in the meantime means a delay to all trains concerned until new orders can be issued.

Thus, until better means were thought of, the time-table and train-order method of operation handled the burden of moving traffic in as orderly and expeditious a manner as possible. At times, especially during dense traffic periods or when something unpredictable disrupted the planned movement of traffic, those concerned with the directing of train movements were overtaxed to the point where costly traffic delays occurred.

GENERAL DESCRIPTION OF cTc

Centralized traffic control, an original development of the General Railway Signal Company, was first installed in 1927. Effective October 1, 1950, the U. S. Interstate Commerce Commission broadened the long-familiar term "centralized traffic control" to "traffic control system," defining it as follows:

> A block system under which train movements are authorized by block signals whose indications supersede the superiority of trains for both opposing and following movements on the same track.

For the sake of convenience in reference and because of established custom, we shall refer to the system in our description as "centralized traffic control" or "cTc" for short.

In practice, a centralized traffic control installation is made up of a succession of remotely controlled interlockings, usually with automatic block signals provided on the intervening trackage. Such an arrangement may be adapted to practically any electric signal installation and to single- or multiple-track roads. A control machine, located in an open office

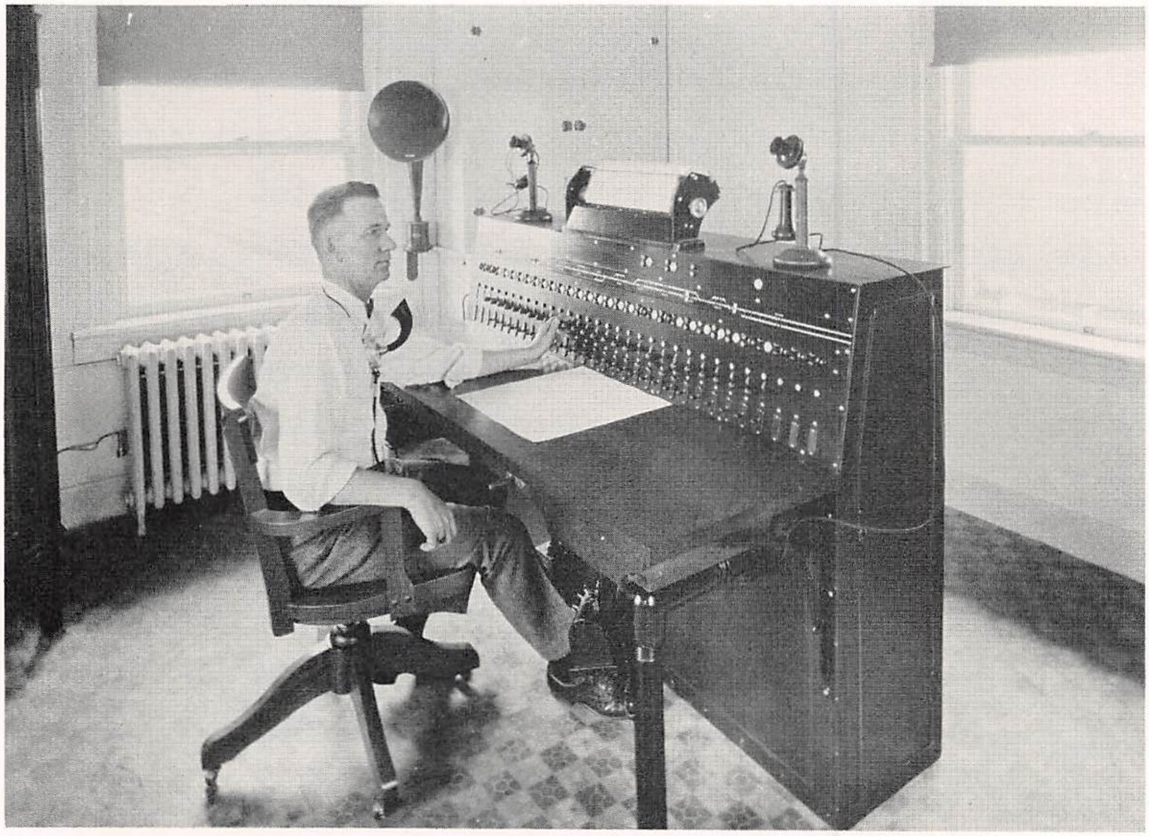

Figure 61. The first installation of centralized traffic control was between Stanley and Berwick, Ohio, on the New York Central System. This is the original control machine at Fostoria, Ohio, in service July 25, 1927.

within, adjacent to, or remote from the installation, provides means for initiating the desired controls and for displaying the indications, which, automatically and continuously, keep the operator informed of train movements and track conditions. Important switches, crossovers, etc. are usually power operated to expedite the movement of trains into and out of sidings, junctions, over crossovers, etc.

cTc OPERATING BENEFITS

cTc cuts train time spent en route.

cTc increases track capacity.

cTc increases the flexibility of operation.

cTc steps up gross ton-miles per train-hour.

cTc increases the availability of cars, locomotives, and train crews.

cTc expedites traffic regardless of its nature, the conditions, the time or the order in which it enters cTc territory.

cTc is far more economical to install and maintain than additional track.

cTc increases safety of train operation.

The cost of installing centralized traffic control and the return on the investment will vary with local conditions, that is, with what facilities existed prior to the installation and what method of operation was in use prior to the installation. It is not uncommon for the annual return to average from 15% to 30% on the investment - in some cases even higher. Oftentimes, a number of manually operated interlockers are retired by consolidating the control of their functions in one cTc machine. In such cases, considerable reductions in annual maintenance and operating costs are usually realized.

The continuous and automatic up-to-the-minute information on track conditions and on the whereabouts and progress of every train, plus the ability to operate switches and signals nearby or miles away, eliminate delays and increase track capacities. Trains are directed at the time and at the place the desired action is to be taken. Under normal conditions, efficiency and economy of operation are increased. Under abnormal conditions, such as bad weather, peak traffic periods, etc., the benefits of cTc are really outstanding.

The best way to evaluate cTc is to review the figures furnished by some of the railroads using it. Take, for example, the first installation of cTc, made in 1927 between Stanley and Berwick, Ohio, 40.2 miles, on the New York Central - 36.9 miles of single track and 3.3 miles of double track. 32 power-operated switches and 102 controlled signals are included in the territory.

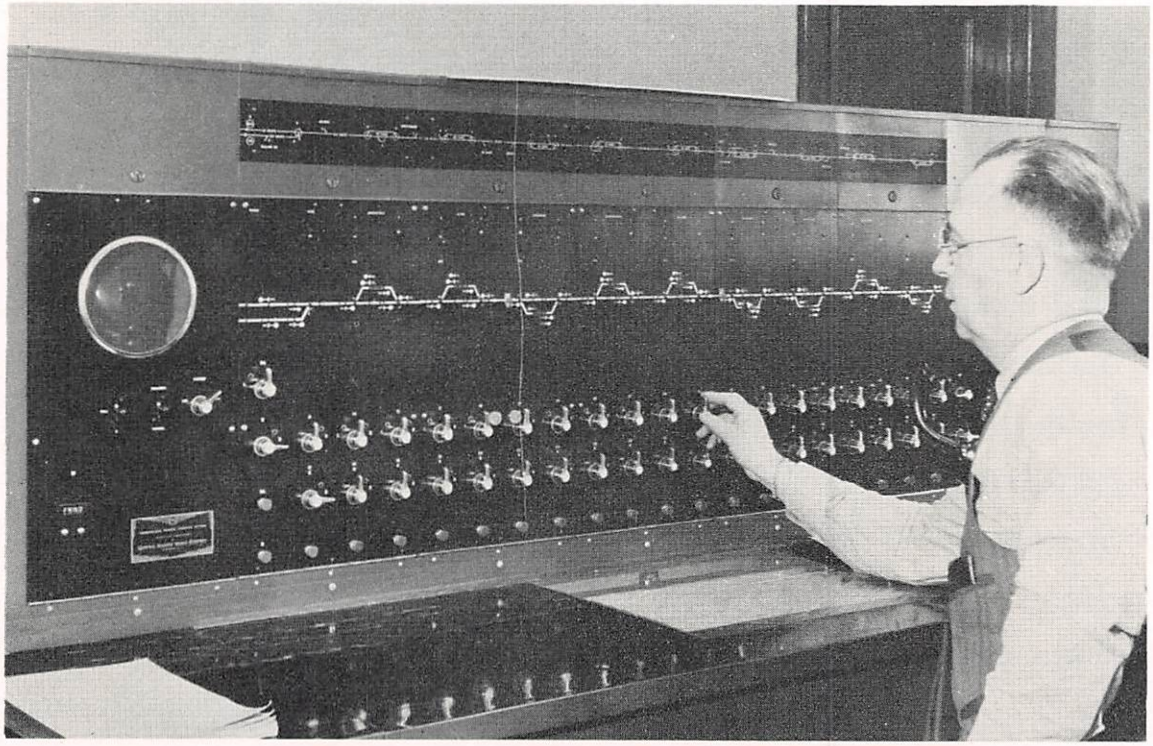

Figure 62. cTc control machine at Halifax, Nova Scotia, on the Canadian National Railways.

At the time of installation, the problem was insufficient traffic capacity, a bottleneck in the single-track territory. After the installation of cTc, the following benefits were realized:

Freight train speed increased 36%
Gross ton-miles per train-hour increased 39%
Traffic capacity increased 40%
Gross tons per train increased 2%
Freight train-hours per trip decreased 26%
Minutes saved per freight-train-mile 1.8

The annual savings amounted to $348,518, or 65% of the installation cost. This amount was arrived at in part by saving the cost of double tracking this territory, an estimated $2,000,000. The 40% increase in traffic capacity broke the bottleneck.

Another installation of note is on the Canadian National Railways between Moncton, N. B. and Halifax, N. S. Included in this territory is an operating district 124.7 miles long between Moncton, N. B. and Truro, N. S. cTc was installed on this district in 1941. Approximately 100 miles of this line is single track. Here again the problem was insufficient track capacity. To have double tracked the 100 or so miles of single track would have cost approximately $5,000,000, and it would have required at least a couple of years to complete the project. cTc was installed and in service in only slightly more than 6 months. The cost was proportionally less. Prior to cTc, operation was by the time-table train-order method.

After cTc was in service, the average through freight train went from 13.8 miles per hour to 18.1 miles per hour - a 30% increase. This average speed takes in all enroute time, terminal to terminal, including stops for water, for the setting out and picking up of cars, and for entering, leaving, and waiting on sidings when necessary. Actually, the average through freight train enroute time is reduced from 9 hours to 6 hours and 54 minutes - a 24% reduction.

These benefits were realized despite the fact that the gross ton-miles increased 14.6%, and the net ton-miles increased 22.9% after cTc was installed. It is interesting to note that for the two typical months chosen for the comparative study, before and after cTc, 115 more trains were handled during the month after cTc was installed than during the similar month before. Remembering that train interference increases directly with traffic density, we can better appreciate the efficiency and expediency possible with cTc.

Interesting operating highlights recorded on this installation are: 36 special passenger trains were handled in one day in addition to the usual traffic, 78 trains have been handled in one day with, at one time, 22 trains on 48 miles of the line. Numerous non-stop meets are made in the single-track territory. The capacity of the line was increased 50 to 70%. The decreased enroute time and faster terminal clearance so increased the availability of motive power that it was estimated that in the first winter eight locomotives in effect, were released for use elsewhere. And last but not least, safety of operation was increased.

An official of the Missouri Pacific Railway says the following regarding the large mileage of G-R-S cTc on his road:

"A comprehensive study of comparable gains has not yet been completed, but it seems safe to say that on the Arkansas Division our trains are getting over our 324.6 miles of roadway about five hours faster than would be possible without cTc."

What may perhaps be termed one of the busiest single tracks in the world is on the Missouri Pacific, 27 miles between Roots and Raddle, Illinois. This stretch of single track connects two sections of double track. As many as 84 trains, some of them more than 100 cars long, have traversed this section in a single day. The average is 70 trains daily.

Prior to 1938, when an average of 55 trains a day was handled by train order and time table, it was not unusual for trains to take 3 hours to traverse this 27 miles. Figures taken, after cTc was installed, on a day when 77 trains moved over this section show a number of freights traversed it in less than 90 minutes. Here again, the perfect coordination of train movement information with the directing that is possible with cTc has eliminated previously unavoidable delays.

In 1940, the Delaware and Hudson Railroad installed G-R-S cTc on one section of their mainline and, as a result, removed 23 miles of third track and found that they were better able to handle the traffic on the remaining two tracks equipped with cTc than was possible with the three tracks prior to the installation of cTc.

At another point on their lines, in 1936, cTc on 6 miles of double track

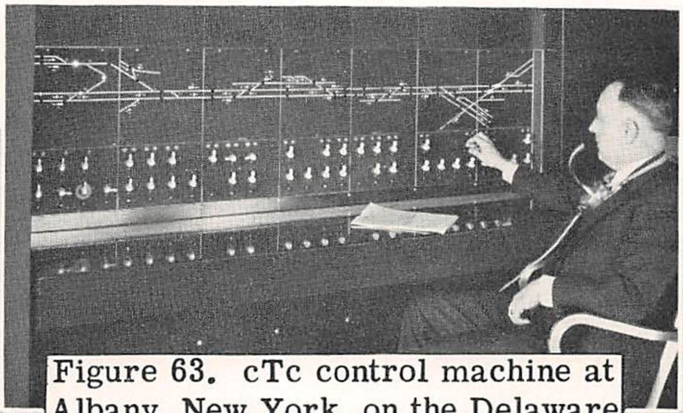

Figure 63. cTc control machine at Albany, New York, on the Delaware and Hudson Railroad.

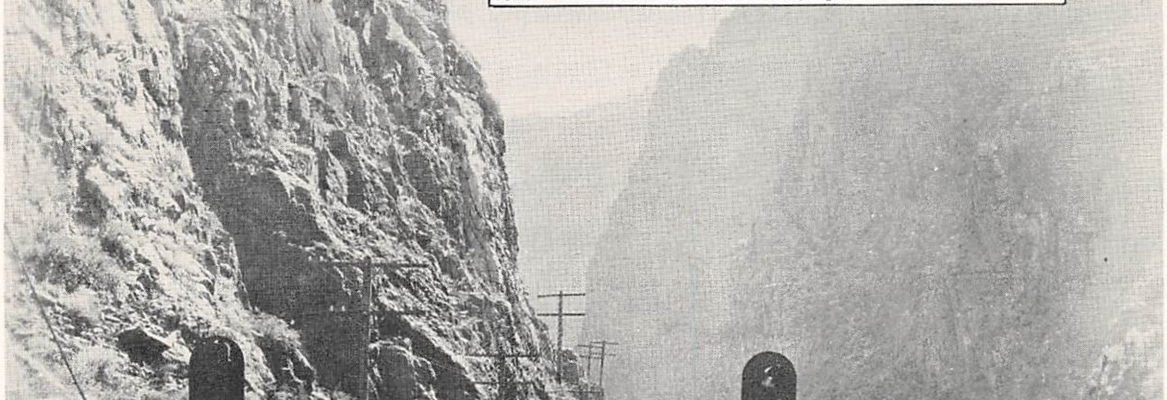

Figure 64. cTc helps speed traffic through mountainous territory on the Denver and Rio Grande Western Railroad.

resulted in the elimination of four interlockers. As many as 339 train and locomotive movements are handled daily in this 6-mile territory, all directed from the one control machine. Usually, the biggest benefits of cTc are realized on long stretches of track. However, as on the Delaware and Hudson, short sections of track with their own peculiar operating problems can often use cTc to effect large savings in both train time and operating expenses.

The Denver and Rio Grande Western has in service over 500 miles of G-R-S cTc, most of it in rugged Rocky Mountain territory. During World War II, the Denver and Rio Grande handled a 97.3% average increase in traffic. At that, on one 107-mile section, freight train time was cut 2 hours. At one time, 19 non-stop meets were recorded in 3-1/2 hours.

On the Denver and Salt Lake line which cuts a direct route through the Rocky Mountains (via Moffat Tunnel), linking the Denver and Rio Grande Western Railroad between Denver and Orestod, increasing traffic had brought about a sharp decline in efficiency. Gross ton-miles per train-hour dipped 17% and average train speeds fell 20%. Many trains were forced to detour. After installation of cTc, in 1942, not only were the detours eliminated, but, despite a traffic increase of 214%, average train speeds were stepped up.

Other railroads have had similar experience with cTc - the Chicago, Burlington and Quincy; the Louisville and Nashville; the Boston and Maine; the Texas and Pacific; and many others.

THE cTc OPERATING PICTURE

Since the operator of a cTc machine has direct control over many functions previously handled by wayside operators, such indications as will facilitate the planning of train movements and the manipulation of the control machine to direct the execution of those movements with maximum efficiency have been incorporated in the control panels. In fact, the usual cTc machine provides more complete information, automatically and quickly, than would be possible with wayside operators.

Individual controls are provided for all power-operated switches (and, if desired, all electrically locked hand-operated switches) and for all interlocked signals, that is, signals located at controlled points such as ends of sidings, crossovers, junctions, etc. The automatic block intermediate wayside signals located between controlled points operate inherently as a part of the system, but their individual controls are simply field circuits, arranged for automatic operation. Other wayside facilities such as employee call devices, tunnel door locks, etc. may be placed under the control of the cTc operator if desired.

Figure 65, 66, 67, page 116, show typical cTc control machines. If the territory to be controlled is extensive, say one hundred miles or more, the control machine (usually a floor mounting model) may be L or U-shaped, as shown in Figure 65. This arrangement brings all the panels within convenient reach of the operator. Figure 66 shows a typical control machine for mounting on a desk or table.

Figure 67 is a floor mounting model. On this machine you may also see an example of a supplementary track diagram (at the top of the control panel). Such a diagram shows car capacity of sidings, lengths of intermediate tracks, and other information helpful to operation.

Referring to the control panels and track layout shown in Figure 68, on foldout page 121, manipulation of the levers, etc. and the various indications and their meanings are as follows: at the top of the control panels are engraved the names of the controlled points or sidings. Below these and above the track diagram are located the power-off lights, one for each

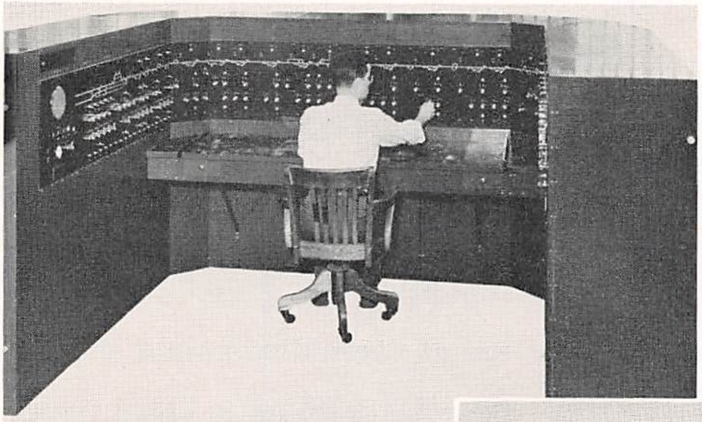

Figure 65. Larger control machines may be U-shaped, as this one on the Chicago, Burlington and Quincy R.R.

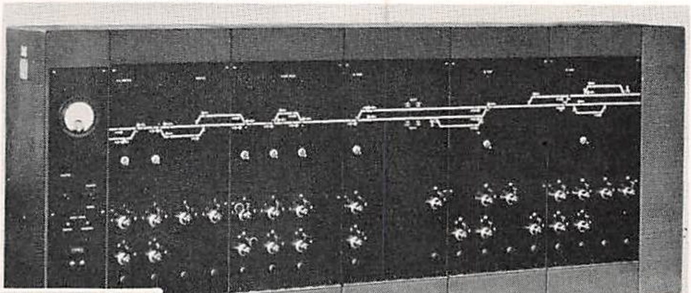

Figure 66. Type B, table mounting, cTc control machine.

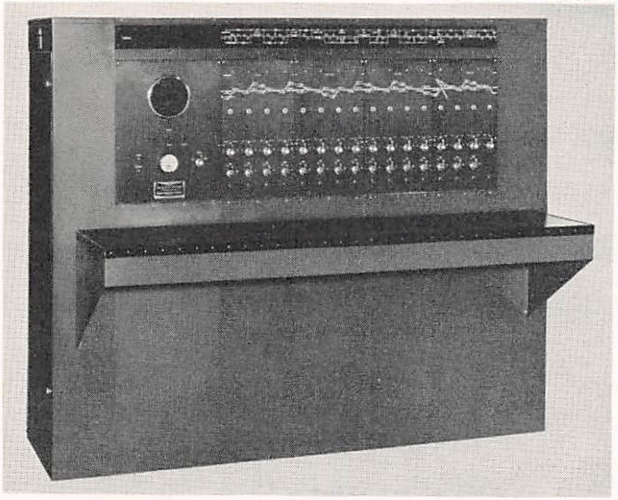

Figure 67. Type C, floor mounting, cTc control machine.

controlled point or field location. These lights are normally dark. When steadily illuminated (red), they indicate that the a-c. power is off at that location. If the installation is coded cTc, these lights will be lighted throughout the duration of an indication cycle from their field location. Should the a-c. power be off and a light is burning steady, then it will be extinguished throughout the duration of an indication cycle from its respective field location. This feature keeps the operator informed as to power conditions at the field location and also enables him to readily identify the field locations sending in an indication. Both are valuable in event of an operating abnormality.

Next, we have the engraved track diagram, laid out in geographic representation of the territory controlled. Adjacent to it are signal symbols with identifying numbers and the number or name of the switch or crossover or other controlled facility. Within the track line itself are located the track-occupancy indicating lights for different sections of track circuited track. For sections not track circuited, token holes are provided so that the operator may post pertinent information. For example, a work train or a damaged car may be on a non-track-circuited siding. By posting a token bearing the train number or the word "cripple", he can keep himself and other operators informed of this condition. White lights are generally provided for approach and intermediate track sections and red lights for the "OS" track sections (detector track sections within controlled points). These lights are normally dark and are illuminated during track occupancy or in event of a broken rail or any other condition that causes the track relay to open its front contacts. An audible signal, bell or buzzer, may be provided to work with the OS lights or important approach lights. These are usually arranged to sound momentarily at the time the track-occupancy indication is first displayed.

Below the track diagram are the employee-call switches, usually one for each controlled point. Such devices (at the field location) may be a horn, ringer or light, or a combination thereof. The switches controlling such devices are two-position, on and off.

Next are shown the signal-clear indication lights, two for each signal lever. As shown, the indications are directional, that is, at lever 15 the light representing the signal governing movements toward the left is dark while the one representing the signals governing movements toward the right is lighted, indicating that a corresponding signal is clear in the field.

Next, are the signal levers, which are three-position rotary switches. Their normal position is center (vertical) which calls for the corresponding group of signals to display their stop aspects. Turning a lever to the right (as lever 15 is shown) calls for a signal governing movement toward the right to clear; to the left for a signal governing movement toward the left (see lever 19). The selection as regards which of two or more signals governing in the same direction will clear is a field function, controlled by local signal selection circuits taken through switch-repeater relays. cTc controlled signals are usually arranged for stick operation, that is, they are automatically put to stop upon acceptance by a train. They will remain at stop until again cleared by the operator. Non-automatic operation may be provided if desired.

Below the signal levers are the switch levers, one for each switch or crossover associated with the signals governed by the lever above. These levers are also rotary switches, normally two-position as shown, having the vertical position (see lever 18) as normal. Turning 90 degrees to the right calls for the switch reverse (see lever 16). Engraved letters N and R show normal and reverse positions.

Each rotary switch used in G-R-S control machines is designed to accommodate a lamp in its barrel which, when lighted, shines through a translucent insert. This is known as the switch correspondence light. When lighted, it indicates that the switch or crossover in the field is not in correspondence with the position of its controlling lever. Some roads prefer to use this lamp to indicate that the associated switch is electrically locked in the field. In such case, the switch correspondence light is located in the panel directly underneath the lever.

At the bottom of the panel are shown the start buttons, ordinarily used only if the cTc system is coded. When controls are to be sent out, say for example, to reverse switch 28 and clear signal 27R at Dayton for the train shown leaving Cortland, the operator turns signal lever 27 and switch lever 28 to the right. Then he pushes the start button directly below levers 27 and 28. The transmission of the controls to the field will not begin until after the start button is pushed. The control message, received and deciphered in the field, will ask for switch 28 to reverse and then for the lower unit on signal 27R to clear, indicating that a diverging route is set up. The execution of these controls will, of course, be subject to the local interlocking circuits at the location, including detector locking, approach locking, track and block conditions, etc.

At the time switch lever 28 is turned to the right, the switch-correspondence light in the barrel of the lever is lighted, indicating to the operator that the switch in the field is not in correspondence with the position of the lever. This light remains lighted until an indication message is received in the control office to the effect that the switch is over (reverse) and locked. When an indication message is received to the effect that signal 27R has cleared, the signal-clear indication light above and to the right of signal lever 27 is lighted.

The foregoing control panel description is of an assumed typical panel. Variations according to the individual railroad's preference may be made. For example, some roads prefer one lamp in the barrel of the signal lever to indicate signal-clear, whether right- or left-hand signal, instead of the two directional signal-clear indication lamps shown. Another feature sometimes provided is a lock light for each switch lever. This lamp may be carried in the barrel of the switch lever, with the switch-correspondence lamp located directly below the lever, or vice versa. When lighted, the lock light indicates that the switch is electrically locked in the field and will not respond to controls asking for a change in its position. Signal and switch levers may be transposed, the switch above and the signal below. Switch levers may be three-position, arranged to call for the switch reverse with lever horizontal to the right or to the left. In this way, if a train movement is to be made toward the right, all levers being positioned (other than normal) for such a move may be positioned toward the right; if to the left, all levers would point left. Another push-button may be added to be operated in conjunction with the signal lever when a non-automatic (call-on) signal is to be cleared. Such an arrangement insures against the displaying of such an indication except when deliberately executed by the operator.

Local field circuits may be arranged for either of two basic schemes of cTc operation: with or without preconditioning. With preconditioning permitted, the controls required to change a route for a second train may be transmitted to and stored at a field location in preparation for the second train while a first train is occupying a conflicting route. With this arrangement, the stored controls will automatically change the route as soon as the locking circuits are released by the departure of the first train. This means that with preconditioning, controls can be initiated by the operator to line up the second route as soon as indications on the control panel show that the first train has occupied the first route. This type of operation tends to expedite train movements, particularly when used at points where trains meet or pass. Without preconditioning, the operator must wait until indications are displayed telling him that the first train has departed before he can initiate controls asking for a route change.

Another feature sometimes incorporated in the control machine is to have exit lights provided. Exit lights assist the operator in readily determining if he has lined up the desired route in its entirety before he pushes the start buttons and sends the controls to the field for execution. This

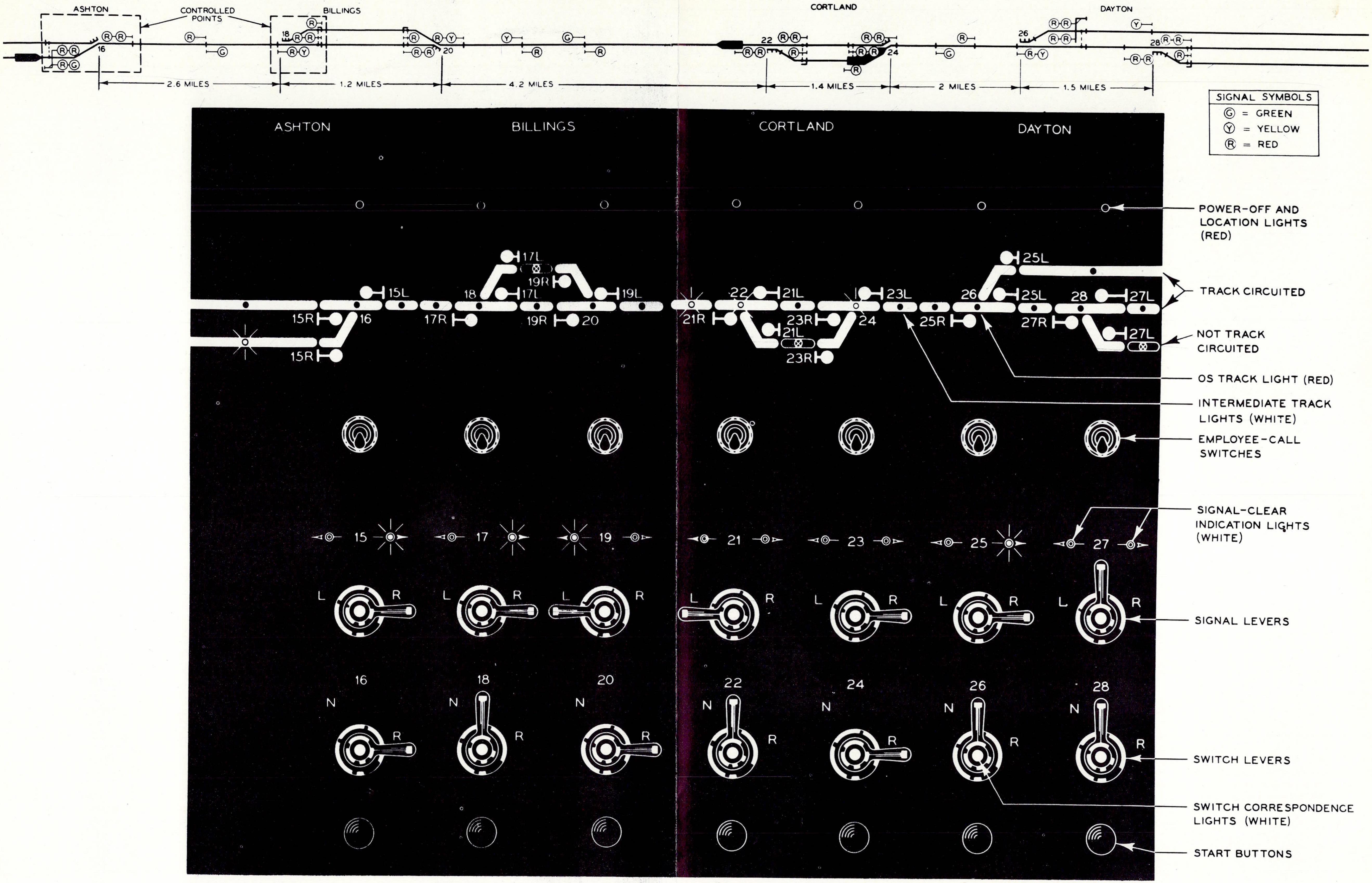
ASHTON
CONTROLLED POINTS
BILLINGS
CORTLAND
DAYTON
2.6 MILES
1.2 MILES
4.2 MILES
1.4 MILES
2 MILES
1.5 MILES
SIGNAL SYMBOLS
Ⓖ = GREEN
Ⓨ = YELLOW
Ⓡ = RED
ASHTON
BILLINGS
CORTLAND
DAYTON
15L
15R
16
17L
17R
18
19R
19L
20
21L
21R
22
23L
23R
24
25L
25R
26
27L
27R
28
POWER-OFF AND LOCATION LIGHTS (RED)
TRACK CIRCUITED
NOT TRACK CIRCUITED
OS TRACK LIGHT (RED)
INTERMEDIATE TRACK LIGHTS (WHITE)
EMPLOYEE-CALL SWITCHES
SIGNAL-CLEAR INDICATION LIGHTS (WHITE)
15
17
19
21
23
25
27
L
R
SIGNAL LEVERS
16
18
20
22
24
26
28
N
R
SWITCH LEVERS
SWITCH CORRESPONDENCE LIGHTS (WHITE)
START BUTTONS

Figure 68. Typical cTc layout and associated control panels.

is of particular value for layouts where a number of possible routes diverge from any given entrance point. When the operator desires a certain route, he first positions all required switch and signal levers. At this time an exit light will be lighted at the point on the engraved track diagram showing the point to which his route lineup leads or, in other words, to the point where the train will exit. He is thus assured that he had positioned all levers properly and may then push the required start buttons to begin the transmission of the controls to the field.

If the system is coded cTc, a succession of controls may be initiated on the control panel at one time. The system will store such initiated controls and release them, one at a time, for transmission to the field in rapid succession without further attention on the part of the operator. Any controls so stored awaiting their turn to be transmitted may be cancelled by the operator, if desired.

If it is considered necessary to verify the indications from any field location, a recheck switch provided on the control machine's master panel may be operated in conjunction with the start button for the particular field location. By means of this facility, a complete check of the indications from a field location may be made without disturbing any of the field functions, that is, without changing the position of a switch or the indication displayed by a signal.

If some abnormal condition at one of the field locations causes that station to repeatedly transmit indications into the control office and thus occupy the line to the exclusion of other stations, a "field cancel" switch provided on the power and test panel of the cTc machine may be manipulated, and the impaired field location will be made to retire and free the line.

A facility often added to machines controlling extensive territories is an automatic train recorder. The recorder may be installed as an integral part of the control machine. Records of train movements are automatically made on a constantly moving chart which is marked with time graduations. The chart is also provided with location identifying lines by means of which the various siding ends, crossovers, junction points, etc. may be identified. Provision is usually made to record the occupancy by a train of each OS track section in the territory. Signal-clear or other desired information may be recorded if desired. The operator, at his convenience, may connect all recording marks made by a train, and in this way the chart becomes a graphic train sheet.

Telephone, telegraph and other desired apparatus may be provided space in the control machine as required. Telephone communication circuits are often combined on the cTc control line with the code circuits. Such facility may be supplemented with the employee call facility, generally provided for use when the operator desires to call a particular field location, and by a voice-actuated call device which will audibly signal the operator when parties call from the field.

In brief, any practical control machine arrangement or operating facility may be incorporated in a G-R-S cTc system.

G-R-S cTc SYSTEMS

There are now four G-R-S cTc systems in general use. The major differences in these systems are whether they are coded or non-coded and, in the coded systems, whether they are duplex* or simplex* in operation and have series or multiple connected line circuits.

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* With duplex operation, outgoing control codes and incoming indication codes may be transmitted simultaneously. With simplex operation, each must take its turn on the line, with control codes being given preference.

1. The unit-wire system (non-coded)

This system was the first to be installed. It requires a wire for the control of each switch and one for the control of associated signals, plus a common return wire. Actually, the switch-control wire is also used to bring in to the control office the signal indications. The switch position and track indications are brought in on another wire.

Unit-wire installations are still being made on short sections where it is not planned to extend the territory later and where a study shows the cost of wire required to be less than the cost of coding equipment.

2. The Type F coded system

The Type F system uses 2 normally deenergized line circuits, usually carried over 3 line wires. In some installations, where the line circuits are carried through long distances of cable, 4 line wires are recommended.

One line wire and the common are used for transmitting the controls outward from the control office. In transmitting controls, codes composed of positive and negative impulses of equal duration are impressed upon the control line circuit by the control office stepper unit. The time required to transmit a control code for a 64-station system is approximately 4 seconds.

The other line wire and the common are used for transmitting the indication information inward to the control office. In transmitting indication information, codes composed of open and closed conditions of the indication line circuit are imposed upon the line by the field location stepper unit. The time required to transmit an indication code for a 64-station system is approximately 4 seconds.

The Type **F** system is arranged for simultaneous transmission of a control code and an indication code to and from the same or different field locations, hence, it is referred to as a duplex system. This means that inbound indications are not held back when outbound controls are being transmitted, or, that controls are not held back by indications. Because of this feature, this system has found special favor in heavy traffic territories.

The control office may be located either at one end of the line circuit for single-end operation or at an intermediate point in the line circuit for double-end operation. With double-end operation, the two line circuits may be operated by the same control office master unit.

3. The Type H coded system

The Type **H** system uses one normally energized line circuit, supplied with energy at the control office and carried over 2 line wires. The control office line relay and all field line relays are series connected in the line circuit. It allocates, in sequence, the use of the 2 line wires for the transmission of controls and indications and is therefore "simplex" in operation, that is, it transmits controls on one cycle and indications on another, but cannot transmit and decipher controls and indications simultaneously. Controls take priority over indications.

In transmitting controls, codes composed of polarized impulses of equal duration are impressed upon the line circuit by the control office stepper. The time required to transmit a control code for a 64-station system is approximately 4 seconds.

Indication codes are transmitted from the field locations to the control office by means of long or short **ON** line current impulses

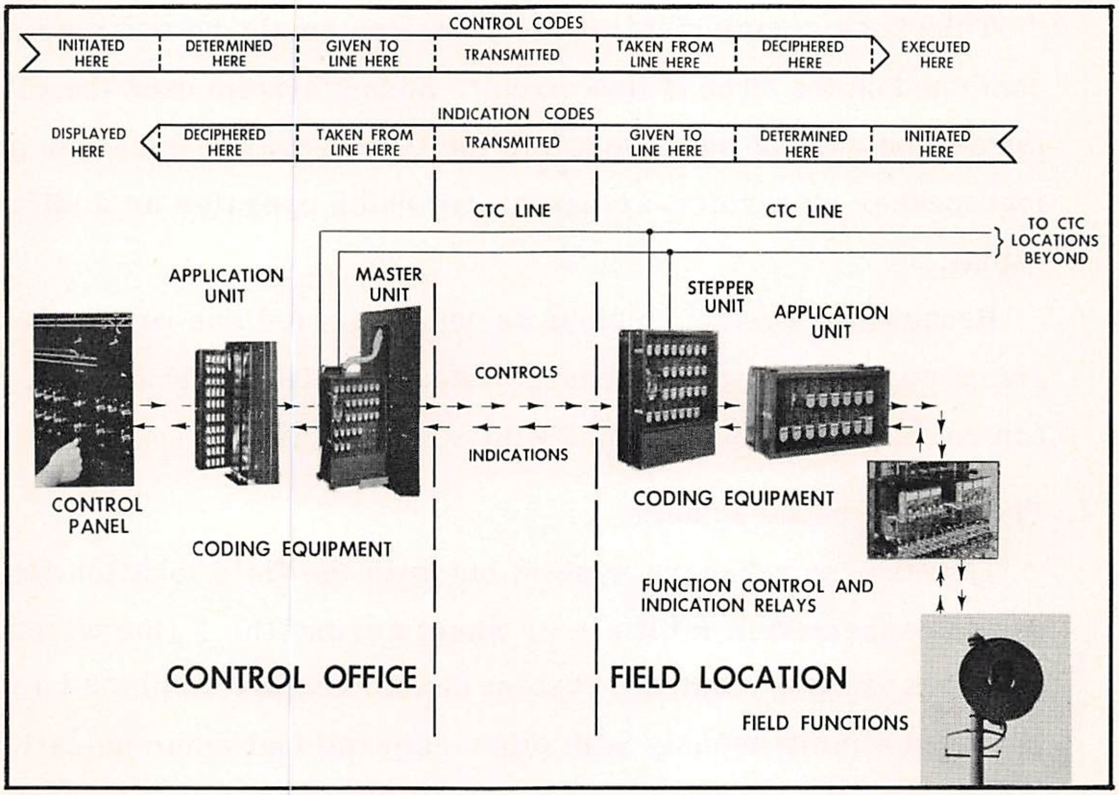

CONTROL CODES
INITIATED HERE
DETERMINED HERE
GIVEN TO LINE HERE
TRANSMITTED
TAKEN FROM LINE HERE
DECIPHERED HERE
EXECUTED HERE
INDICATION CODES
DISPLAYED HERE
DECIPHERED HERE
TAKEN FROM LINE HERE
TRANSMITTED
GIVEN TO LINE HERE
DETERMINED HERE
INITIATED HERE
CTC LINE
CTC LINE
TO CTC LOCATIONS BEYOND
APPLICATION UNIT
MASTER UNIT
STEPPER UNIT
APPLICATION UNIT
CONTROLS
INDICATIONS
CONTROL PANEL
CODING EQUIPMENT
CODING EQUIPMENT
FUNCTION CONTROL AND INDICATION RELAYS
CONTROL OFFICE
FIELD LOCATION
FIELD FUNCTIONS

Figure 69. Organization of G-R-S coded cTc systems. Line may be 2- or 3-wire, and line-connected units may be in series or multiple, depending on system.

without polarization and by long and short **OFF** periods between the line current impulses. The **ON** signifies the periods when line current is flowing, the **OFF** when no line current is flowing. The time required to transmit an indication code is approximately 5.5 to 6 seconds.

The control office may be remote or adjacent to either end of the line for single-end operation. If it is at an intermediate point in the line, double-end operation may be provided by means of 2 control office master or stepper units or by means of a code repeater arrangement. Code repeaters may also be used to extend the operable length of the cTc line or to handle a branch line without looping the main line circuit out and back over the branch.

Telephone communication facilities for employee use may be combined on the Type H line circuit. Such a system uses the cTc for station calling purposes, and the cTc operator is called by loudspeaker or a voice-actuated unit which operates an audible signal.

Because the system employs series-connected line relays, it is giving way to the Type K or shunt system, because the shunt system can be more readily combined with other services.

4. The Type K coded system

This is also a 2-wire system but with the field location line relays connected in multiple or shunt across the 2 line wires. With this arrangement the system can be readily combined and operated simultaneously with other conventional communication services on the same pair of line wires. In addition, the cTc codes can be readily extended to sections beyond the practical limits of direct-current codes by the application of G-R-S carrier control. There is also the advantage that if a line break occurs, the system is operative up to the point of the break. With a series system, the entire system would be inoperative unless sectionalizing equipment were provided.

The Type K system line circuit is normally energized, receiving energy from the control office line battery. Like the Type H system, it allocates, in sequence, the use of 2 line wires for the transmission of controls and indications and is thus simplex in operation.

In transmitting controls, codes are made up of long and short line current impulses and long and short intervals between the line current impulses. The time required to transmit a control code for a 64-station system is approximately 5 to 5.8 seconds.

Indication codes, transmitted from the field locations to the control office, are made up of long or short periods resulting from the shunting and unshunting of the line by a field stepper unit. The time required for the transmission of an indication code is approximately 3.5 to 4.8 seconds. The code transmission times, both control and indication, vary within the limits given above according to whether the system is size 8 (16-station capacity) or size 10 (32-station capacity). Indication code time varies according to the number of indication steps necessary to describe fully the conditions at a particular field location. The greater the system's capacity, or the greater the number of indications, the longer the code transmission time.

The control office may be remote from or adjacent to either end of the installation, or it may be at some intermediate point within the limits of the installation. In the latter case, if the requirements of the section are not such as will exceed the practical operating capacity of the system, the control office master unit may be arranged for double-end operation.

If local conditions are such that it is desired to handle 2 or more sections extending outward from the control office, G-R-S carrier control may be employed. With carrier control, each section may be operated independently of the others, with the first section handled by direct-current codes directly from the control machine, and each succeeding section handled by carrier currents superimposed on the same 2 line wires. Carrier currents of different frequencies are assigned to each section so handled.

Telephone communication facilities for employee use may easily be combined with the cTc on the line circuit. The system may use the cTc for calling outward and a loudspeaker or some suitable audible signal operated by a voice-actuated calling unit for signaling the operator for incoming calls.

THE APPLICATION OF CENTRALIZED TRAFFIC CONTROL

There are many factors that should be given thorough consideration when planning the application of centralized traffic control to a particular section of track: the amount of traffic, its nature, its normal flow, and its peak periods or seasons, present and anticipated; and the plant, that is, existing track, sidings, crossovers, and topography. All of these should be evaluated in a study of the line. This requires the cooperation of many railroad departments, under the guidance of an individual trained and experienced in such work. The General Railway Signal Company has available for such work specially trained engineers, who may be called upon for consultation at any time without obligation.

As a result of such studies, it is possible to predict, with a high degree of accuracy, the operating and economic benefits that may be realized by the installation of centralized traffic control. The general scheme, or, in other words, the amount of equipment which can be economically justified, the cTc system best adapted to the requirements, and many other details, may be determined and decided upon.

There are a number of possible schemes of operation. Any scheme may, of course, be modified to suit particular requirements or to fit particular locations.

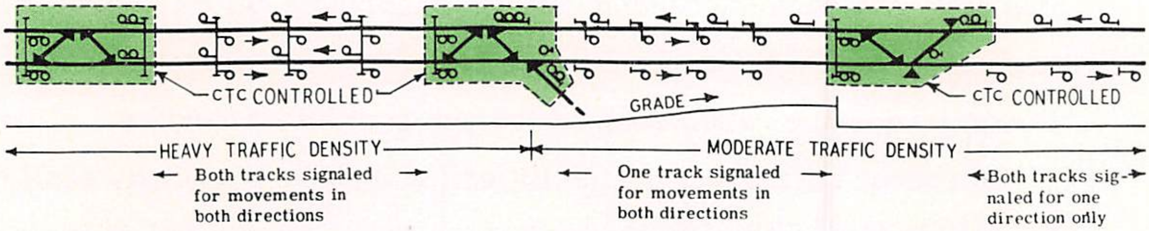

CTC CONTROLLED
GRADE →
cTc CONTROLLED
HEAVY TRAFFIC DENSITY
MODERATE TRAFFIC DENSITY
Both tracks signaled for movements in both directions
One track signaled for movements in both directions
Both tracks signaled for one direction only

Figure 70a. Example of signaling a multiple-track line to suit traffic density and topography.

Take for example a double-track line. As shown in Figure 70a, where the density of traffic is heavy, power-operated crossovers properly spaced with both tracks signaled for movements in both directions will permit maximum utilization of the existing plant. Fast trains may pass the slower trains without either one stopping. Passenger trains may be routed to the track adjacent to the wayside stations and, while they wait at these stations, other trains of the same or opposite direction may pass without interfering. Where grades exist, and traffic does not warrant signaling both tracks for both directions, it is often found advantagous to signal one track for movement in both directions. In this way, if a heavy freight is climbing the hill, faster trains may pass on the other track and thus avoid bunching trains behind the slow one. The entries into these various sections of track are governed by means of the cTc controlled signals located at crossovers, junction points, etc. The intermediate signals are subject to directional control according to the direction of traffic as established by the cTc control of the entering signals.

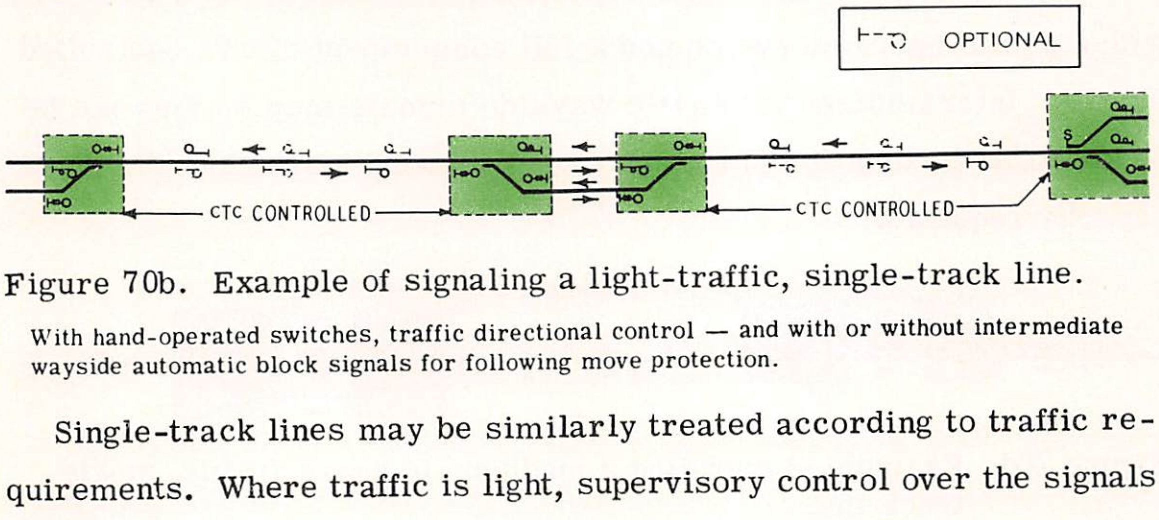


Figure 70b. Example of signaling a light-traffic, single-track line.

With hand-operated switches, traffic directional control — and with or without intermediate wayside automatic block signals for following move protection.

Single-track lines may be similarly treated according to traffic requirements. Where traffic is light, supervisory control over the signals only may be provided, as shown in Figure 70b. In this manner, trains may be directed block to block. They may also be directed to enter sidings, and they may be held in sidings as desired by means of the supervisory control which can be exercised over the leave-siding signals. The track occupancy and signal indications displayed on the control machine enable the operator to utilize all operating opportunities whenever they occur.

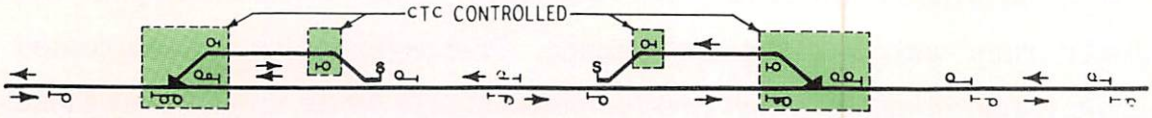


Figure 70c. Example of signaling a light- to medium-traffic, single-track line.

With power- and spring-operated switches — and with or without intermediate wayside automatic block signals for following train protection.

Another scheme, shown in Figure 70c, provides supervisory control over all signals and a power-operated switch at what may be termed the entering ends of the sidings. At the leaving end of each siding, a spring switch is provided together with a cTc controlled leave-siding signal. In this way, practically full utilization can be made of the sidings, each being used in a unidirectional manner as shown. Those sidings that are found to be the most frequently used may be equipped at each end with a power-operated switch and a full complement of cTc controlled signals. Intermediate automatic wayside signals may or may not be provided, according to the frequency of following moves and the track capacity required.

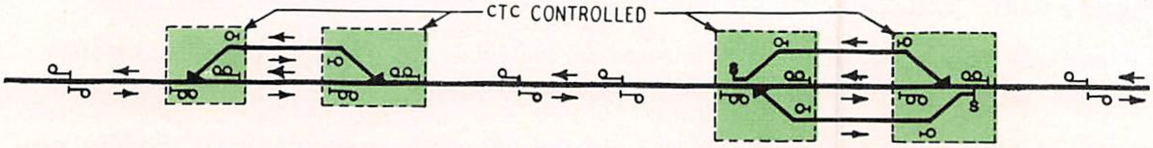


Figure 70d. Example of signaling a medium- to heavy-traffic, single-track line.

With power-operated switches generally — spring-operated switches shown at lap siding may also be power-operated if traffic requirements are such as to warrant provision for normal either-direction use of both sidings. A full complement of intermediate wayside automatic block signals, APB or traffic directionally controlled, is provided. These signals are spaced for maximum track capacity.

For those single-track lines carrying heavy traffic, a full complement of cTc controlled signals with a power-operated switch is provided at each siding end. In this manner, maximum utilization may be made of all siding facilities, regardless of traffic direction or grades. Intermediate automatic wayside signals spaced for maximum track capacity are provided, controlled either by the absolute-permissive-block or traffic-directional method. As shown at the right of Figure 70d, two-siding stations with lap sidings may be equipped for unidirectional use of the sidings by providing a spring switch at the siding-leaving ends. If it is desired to use either or both sidings for normal either-direction running, power-operated switches may be substituted for the spring switches.

As the purpose of centralized traffic control is to direct the movements of trains through a succession of blocks, with the directing being intelligently guided by means of the operating information automatically and continuously furnished the operator in the form of indications, the fundamental scheme is actually one of communication between the field and the control office. Its salient feature is that it is flexible enough to combine with practically any manner of wayside signaling or signal equipment. Thus, wayside signal operation may be by means of steady-energy track circuits with line wires for signal and other controls, or it may be by means of coded track circuits with or without signal-control line wires. Switches may be power-, hand-, or spring-operated. Signals may be of any conventional power type. Many such details are optional and should be given consideration in the final planning. Taking the entire signaling project into consideration, they all have a bearing on the economic return that may be rightfully anticipated from a given installation. Therefore, emphasis must be placed on proper study and engineering when contemplating an installation of centralized traffic control.

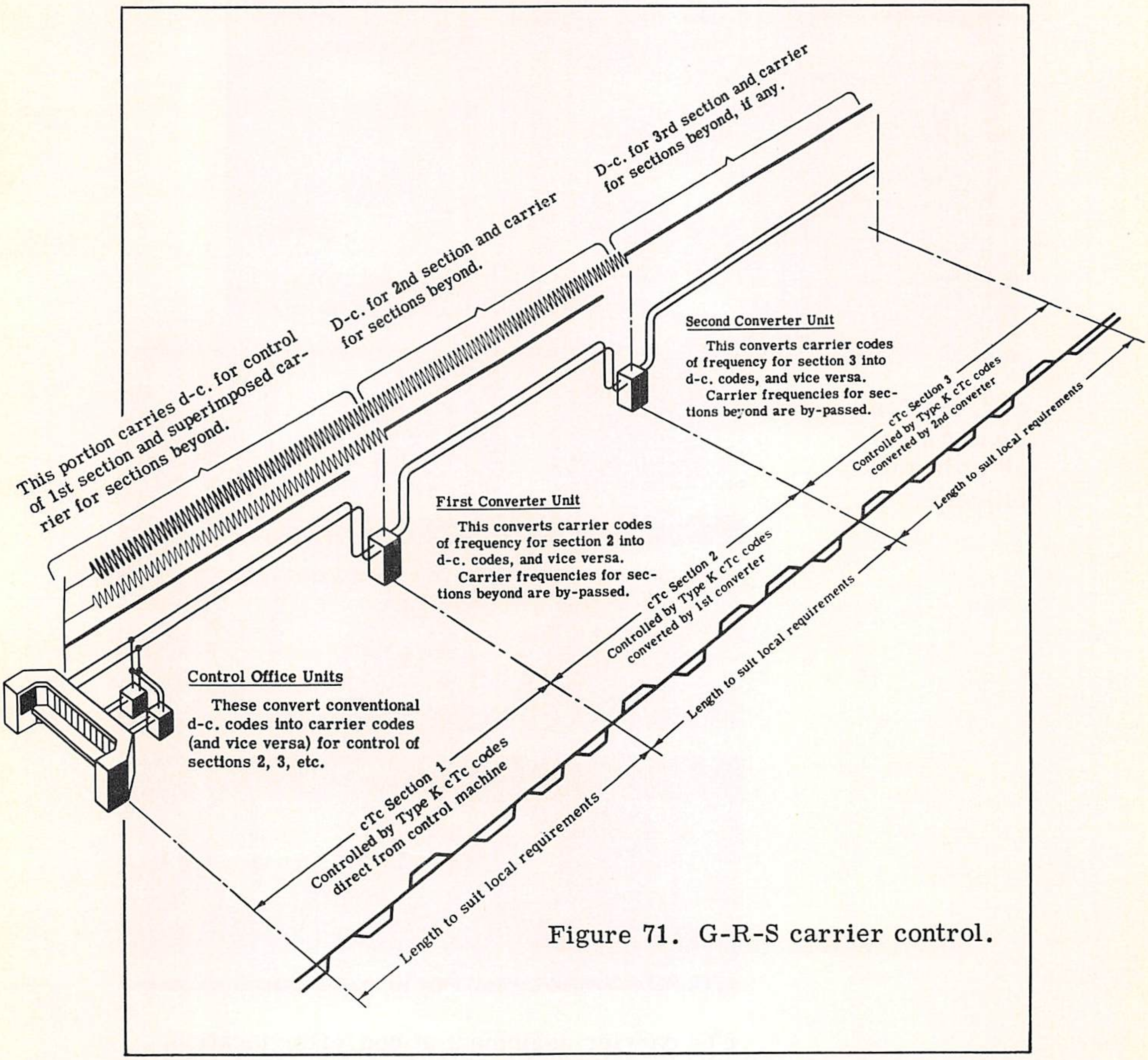
G-R-S CARRIER CONTROL

It is often desirable or necessary to divide a large centralized traffic control territory into two or more sections, each handled independently from the same control office. With coded cTc, this would ordinarily require separate cTc line wires for each section. However, by means of G-R-S carrier control, the same line wires may be used to control 2 or more sections of cTc as shown in Figure 71.

Carrier control is particularly suited for use with G-R-S Type K coded cTc, since that system can readily be combined with other communication facilities.

Carrier control consists, primarily, of providing high-frequency carrier currents which act as a connecting link between the control office and one or more remote sections of coded cTc. The first cTc section may be, and usually is, handled directly from the control office by means of conventional d-c. codes without the aid of carrier. The second section is then remotely controlled from the same control office by means of carrier currents superimposed on the line wires along with the d-c. codes of the first section. At the beginning of the second section, these carrier currents are converted to conventional d-c. code currents for use by locations in the second section. Indication codes are, of course, handled in the reverse manner, that is, they originate as d-c. codes at the field locations in the second section. At the near end, they are converted to carrier currents for transmission to the control office. A third section can be controlled by means of carrier currents of a different frequency, superimposed on the same line wires used for the first and second sections. Additional sections can be controlled in a similar manner if desired.

Carrier control may also be used to control remotely a complete cTc territory from a control office located some distance from the controlled territory. This makes it possible and practical to place the control machine in the railroad's operating headquarters or to centralize the control of two or more operating divisions at one headquarters, an arrangement that is being favored in recent years.


This portion carries d-c. for control of 1st section and superimposed carrier for sections beyond.
D-c. for 2nd section and carrier for sections beyond.
D-c. for 3rd section and carrier for sections beyond, if any.
cTc Section 1 Controlled by Type K cTc codes direct from control machine
Length to suit local requirements
cTc Section 2 Controlled by Type K cTc codes converted by 1st converter
Length to suit local requirements
cTc Section 3 Controlled by Type K cTc codes converted by 2nd converter
Length to suit local requirements

Control Office Units

These convert conventional d-c. codes into carrier codes (and vice versa) for control of sections 2, 3, etc.

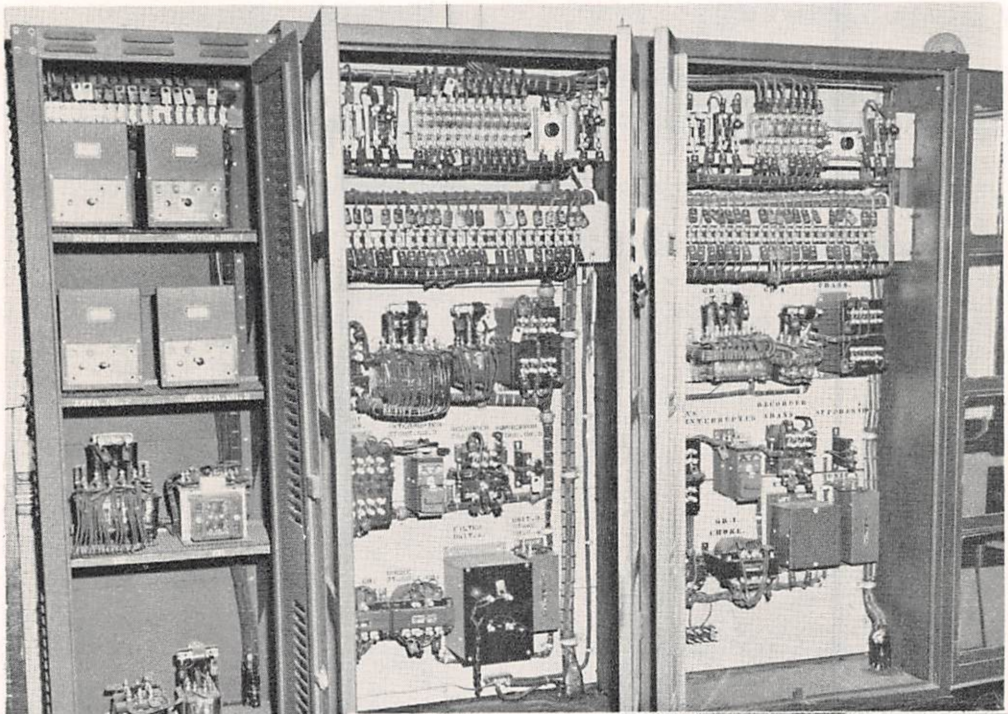
First Converter Unit

This converts carrier codes of frequency for section 2 into d-c. codes, and vice versa. Carrier frequencies for sections beyond are by-passed.

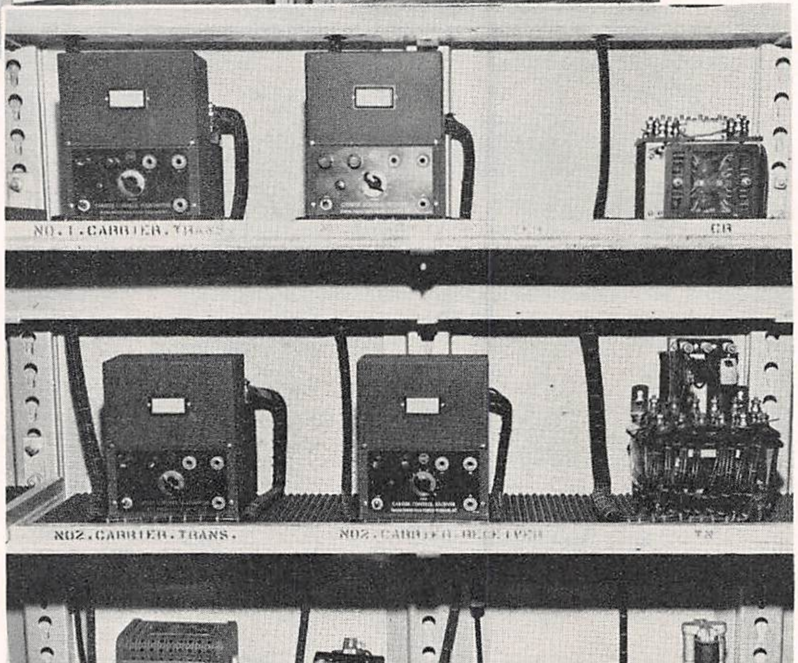
Second Converter Unit

This converts carrier codes of frequency for section 3 into d-c. codes, and vice versa. Carrier frequencies for sections beyond are by-passed.

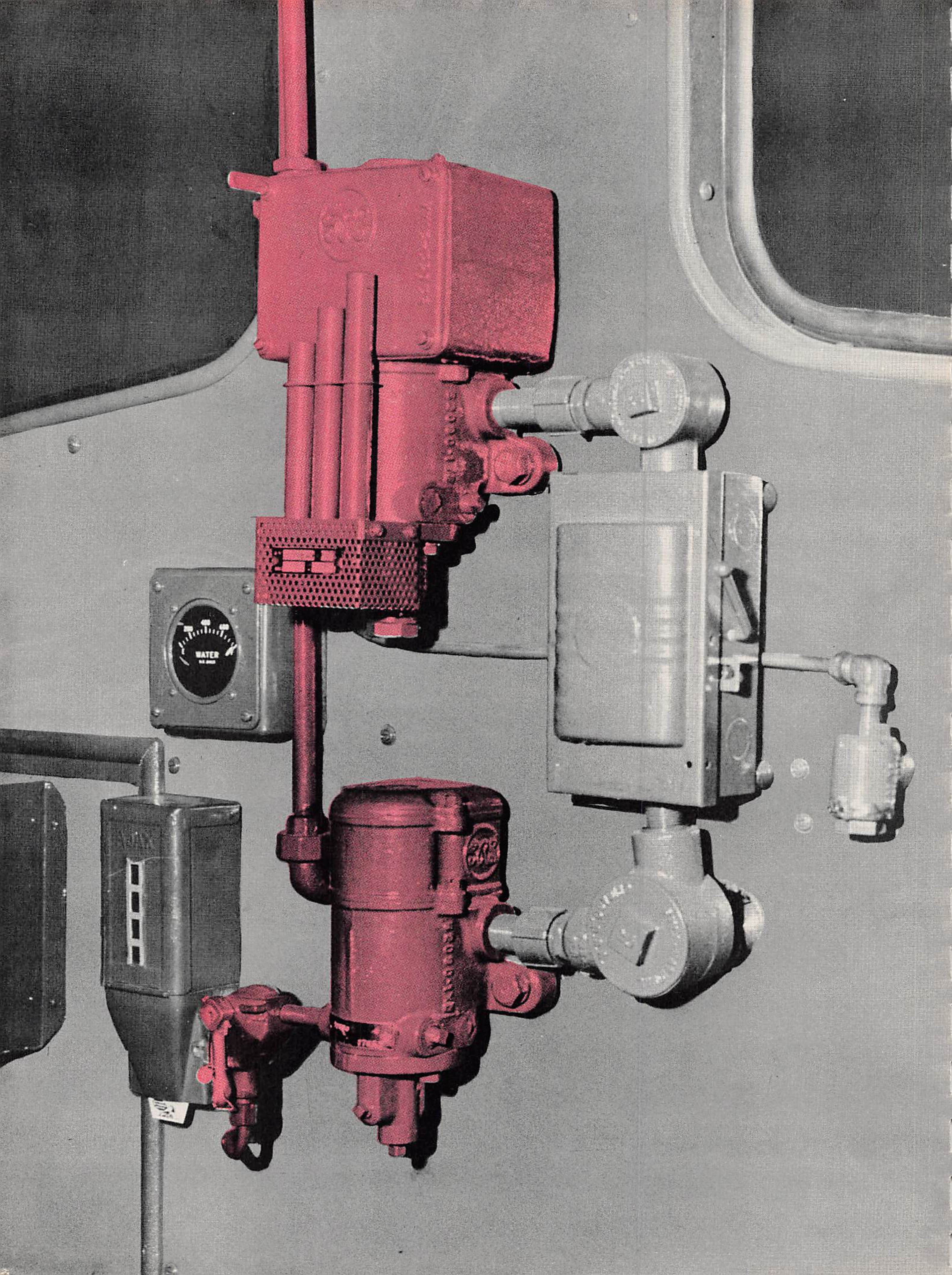
Figure 71. G-R-S carrier control.



cTc carrier equipment at control office.


NO.1.CARRIER.TRANS
CR
NO2.CARRIER.TRANS.
CPR
C.TRANS
TNC

cTc carrier equipment at converter location.


200
400
600
WATER

INTERMITTENT INDUCTIVE TRAIN CONTROL

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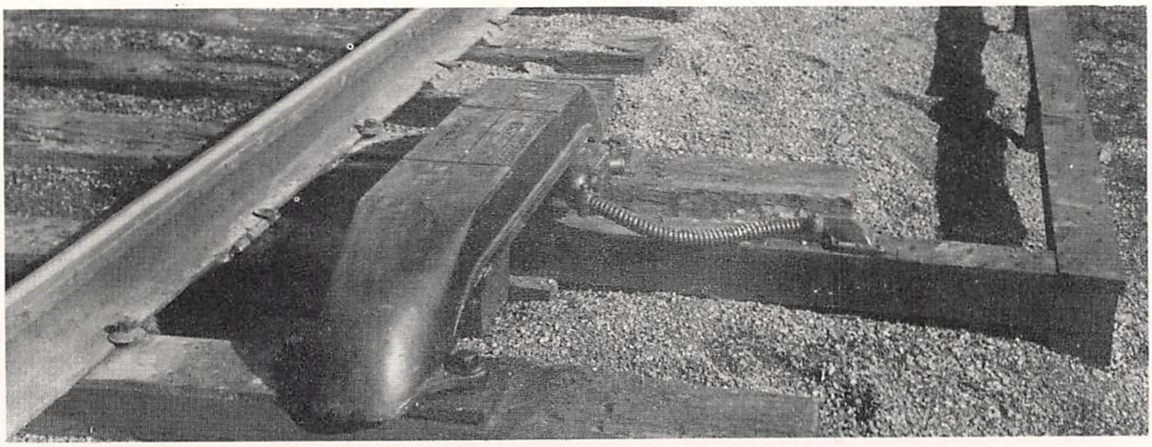


Figure 72. Inductor for G-R-S intermittent inductive train control system.

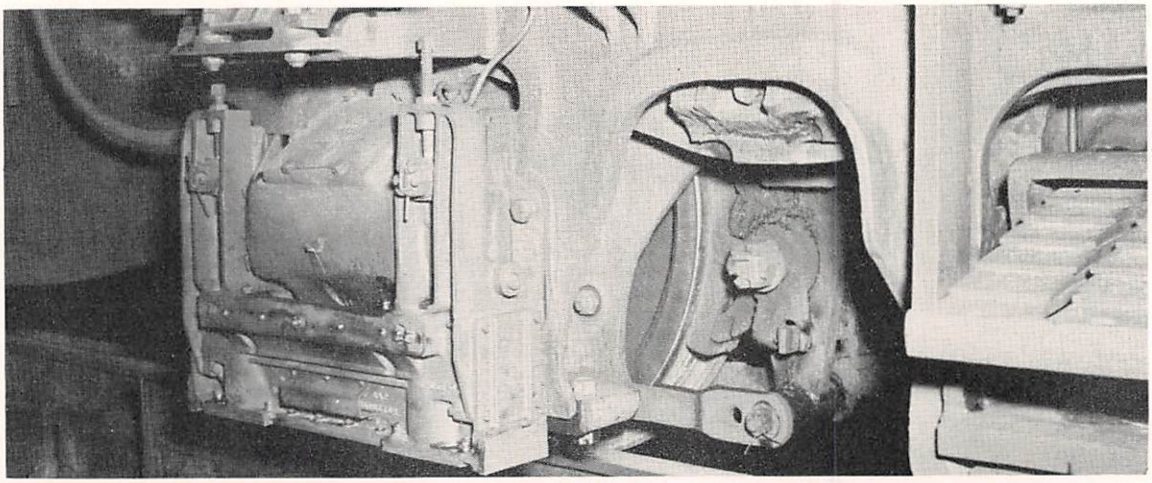


Figure 73. Receiver for G-R-S intermittent inductive train control system, mounted on diesel-electric locomotive journal box.

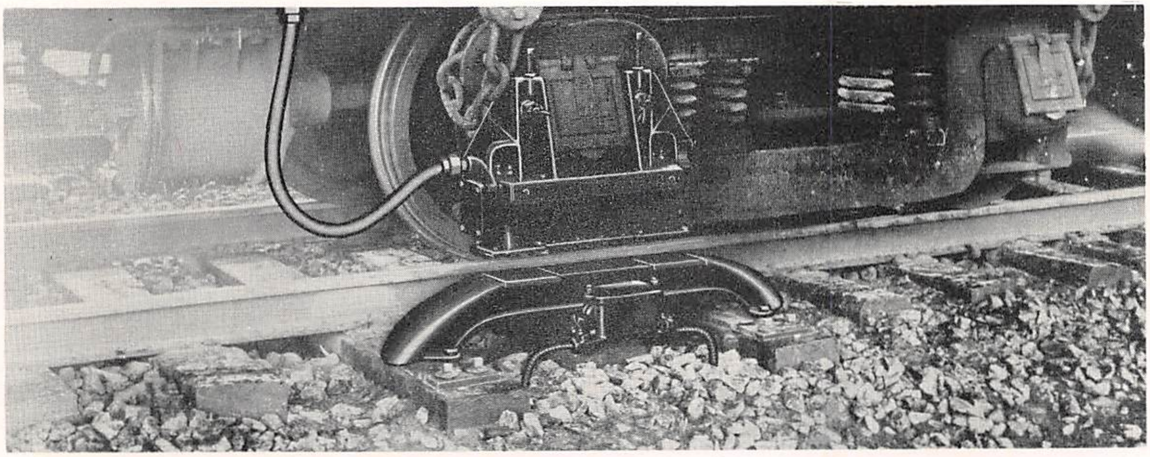


Figure 74. Relative positions of receiver and inductor when passing.

GENERAL DESCRIPTION

It is obvious that the desired operation of a block signal system can be obtained only while the engineman remains alert to the aspects which the signals display, and controls his train in accordance with the signal indications. The G-R-S intermittent inductive train control system is designed to check the engineman's awareness of restrictive wayside signals by requiring him to operate an "acknowledging" contactor immediately before passing such signals. By making acknowledgment at the proper time, the engineman demonstrates his alertness, and the system permits him to retain full control of his train. If he fails to acknowledge properly, an automatic brake application occurs which cannot be released until a reset contactor is operated. The reset circuits may be arranged so that brake release cannot be obtained until (a) train speed has been reduced to a pre-established low value or (b) the train has been stopped completely or (c) a pre-established time interval has elapsed. Furthermore, an automatic brake application also occurs if the acknowledging contactor is held closed for longer than 15 seconds, thus preventing any attempt to nullify the system by blocking the contactor in the acknowledging position.

Magnetic induction is used to transfer controls from the wayside signal circuits to the locomotive equipment. A magnetic structure, called the inductor, is mounted beside the track immediately ahead of each wayside signal. Another magnetic structure, the receiver, is mounted on the side of each locomotive (or tender) so that its pole pieces pass directly over the pole pieces of the inductor with a clearance of about two inches. Typical arrangements of inductors and receivers are shown in Figures 72, 73, and 74.

The effect that the inductor has upon the receiver depends upon the

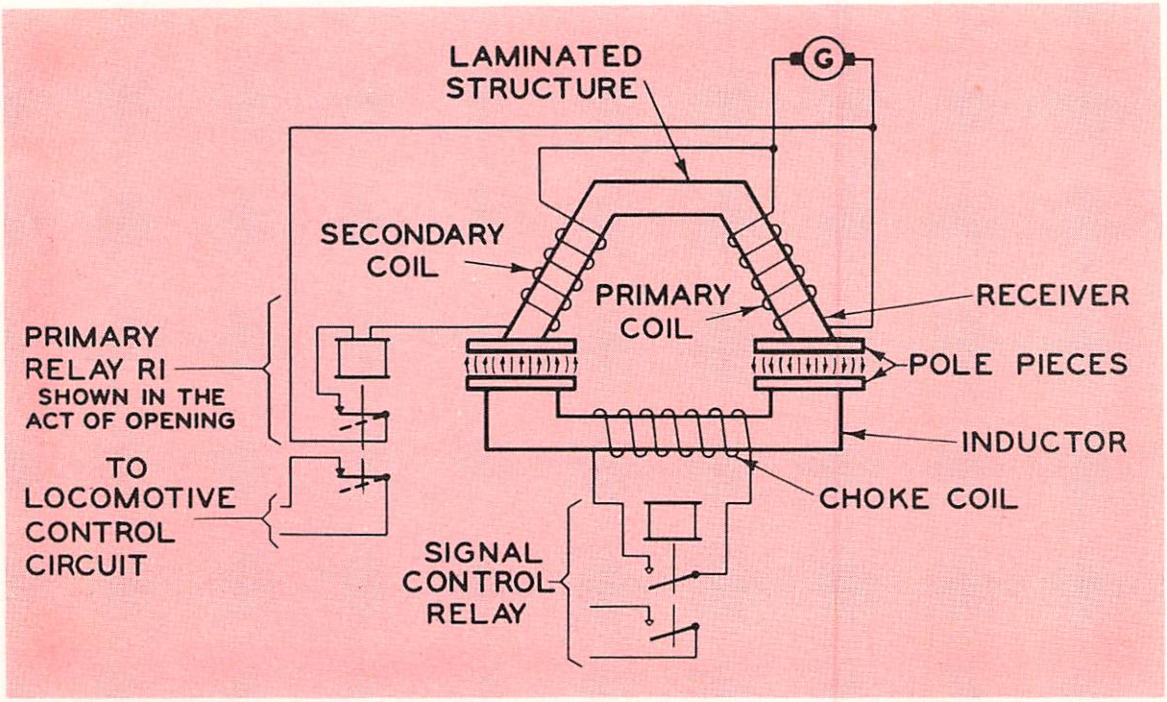

LAMINATED STRUCTURE
G
SECONDARY COIL
PRIMARY COIL
RECEIVER
POLE PIECES
PRIMARY RELAY RI
SHOWN IN THE ACT OF OPENING
INDUCTOR
TO LOCOMOTIVE CONTROL CIRCUIT
CHOKE COIL
SIGNAL CONTROL RELAY

Figure 75. Diagram showing how magnetic induction is used to transfer control from wayside signal circuits to locomotive circuits.

condition of the associated wayside signal. When the signal is clear, the inductor produces only a limited effect on the receiver, not sufficient to actuate the locomotive control circuits. When the signal is restrictive, the effect of the inductor on the receiver is considerably greater, causing a primary relay in the locomotive mechanism to drop away. If the engineman is not making proper acknowledgment when passing a restrictive inductor, the primary relay releases and stays down, the electro-pneumatic valve controlling the brake-applying mechanism is deenergized, and the brakes are automatically applied. They cannot be released until the required reset conditions have been met. If, however, the engineman is making proper acknowledgment, the acknowledging circuits act to energize the primary relay immediately after it releases, and also to hold the electro-pneumatic valve energized during the interval that the primary relay is released. Under these conditions an automatic brake application does not occur, but a cab whistle sounds a short blast while the relay is released. The whistle blast informs the engineman that the locomotive equipment is responding properly to the restrictive wayside signal, and also indicates, by its cessation, that the primary relay is again energized and that the acknowledging contactor may be released.

Figure 75 shows in diagrammatic form how the magnetic linkage between the inductor and receiver is used to control the primary relay. Primary relay R1 on the locomotive, is energized from the generator through one of its own front contacts and the secondary coil wound on the receiver. The battery also energizes the receiver primary coil, setting up a magnetomotive force which produces a magnetic flux in the receiver core. While the locomotive is proceeding along the track between inductors, the flux density thus produced is comparatively small because of the large air gap between the receiver pole pieces. When the receiver passes over an inductor, however, there is an increase in the receiver flux because of the decrease in reluctance of the path between the receiver pole pieces produced by the presence of the inductor. This flux change induces a voltage in the receiver secondary coil which is opposed to the generator voltage. If the flux change is sufficiently rapid, the induced voltage is great enough to drive the voltage across the primary relay below the dropaway value, causing the relay armature to drop away. But if the flux change in the receiver is not so rapid, the voltage induced in the receiver secondary does not reduce the voltage across the relay enough to cause dropaway, and the relay remains in the energized position.

The rate at which flux changes occur in the receiver-inductor magnetic circuit is controlled by the choke coil on the inductor. As shown in Figure 75, the choke coil circuit is opened and closed through a contact on the signal control relay. When the signal control relay is down (restrictive signal), the choke coil circuit is open. Under this condition, no current can flow in the choke coil, and there is no effect on the rate at which flux builds up in the receiver-inductor magnetic path. As a result, the flux changes rapidly as the receiver passes over the inductor, the receiver secondary coil voltage opposing the battery voltage is large, and the primary relay drops away. When the signal is clear, however, the signal control relay is energized, and the choke coil circuit is closed. Under this condition, change in flux in the receiver-inductor magnetic circuit causes a circulating current to flow in the choke coil which produces a magnetomotive force opposed to that in the receiver. This counter-magnetomotive force reduces the rate of change of receiver flux sufficiently so that the induced secondary-coil voltage is no longer great enough to cause the primary relay to drop away, and the relay remains continuously energized.

It will be seen from the foregoing that the locomotive primary relay drops away each time the receiver passes over an inductor at a restrictive signal, but remains energized when the receiver passes over inductors at clear signals. This is exactly the effect required to obtain the desired train control operation. It may also be seen that a permanently restrictive control can be obtained at any desired location merely by using an inductor that does not include a choke coil. Such an inductor (called an unwound inductor) produces the same effect as the inductor previously described with the choke coil in open-circuit condition.

Figures 76 and 77 show typical arrangements of the locomotive apparatus, and Figures 78 through 84 show principal items of equipment carried by the locomotive.

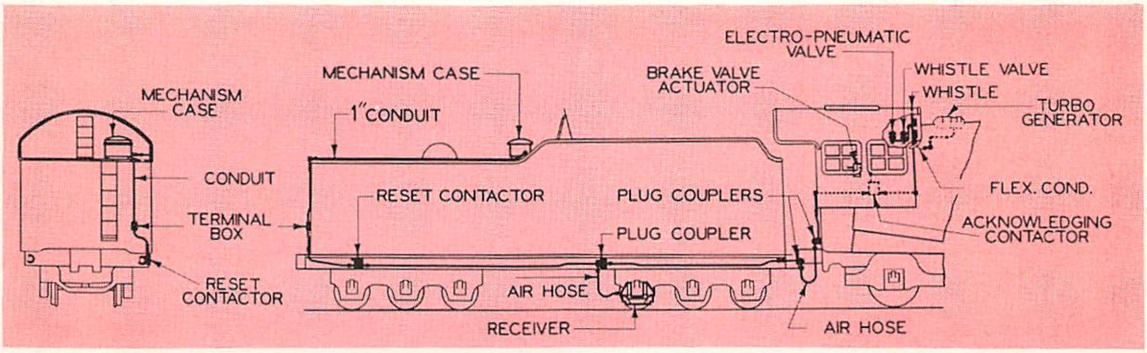

MECHANISM CASE
CONDUIT
TERMINAL BOX
RESET CONTACTOR
MECHANISM CASE
1" CONDUIT
RESET CONTACTOR
PLUG COUPLERS
PLUG COUPLER
AIR HOSE
RECEIVER
ELECTRO-PNEUMATIC VALVE
BRAKE VALVE ACTUATOR
WHISTLE VALVE
WHISTLE
TURBO GENERATOR
FLEX. COND.
ACKNOWLEDGING CONTACTOR
AIR HOSE

Figure 76. Typical arrangement of apparatus, steam locomotive.

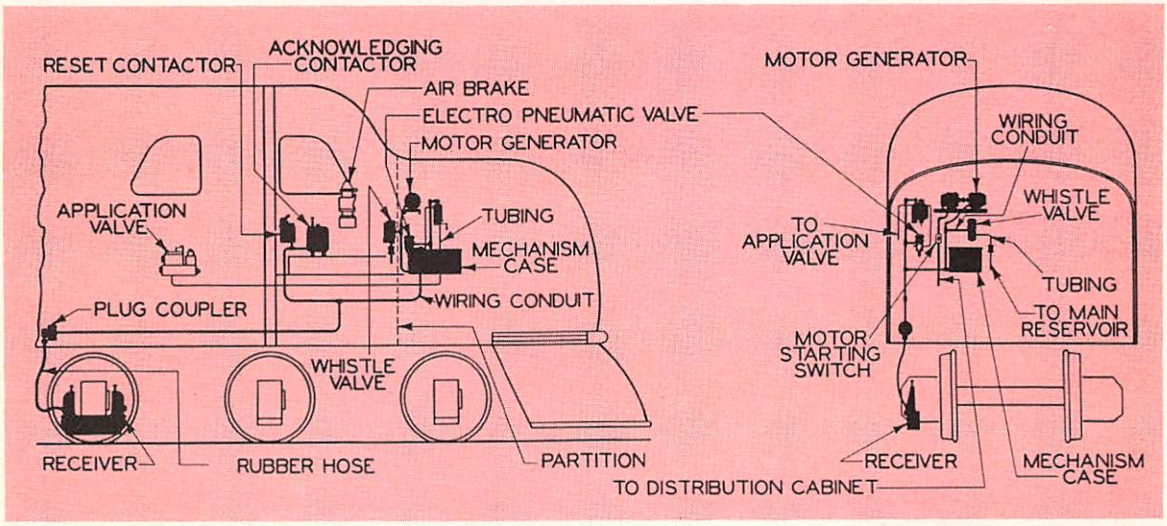

RESET CONTACTOR
ACKNOWLEDGING CONTACTOR
AIR BRAKE
ELECTRO PNEUMATIC VALVE
MOTOR GENERATOR
APPLICATION VALVE
TUBING
MECHANISM CASE
PLUG COUPLER
WIRING CONDUIT
WHISTLE VALVE
RECEIVER
RUBBER HOSE
PARTITION
MOTOR GENERATOR
WIRING CONDUIT
WHISTLE VALVE
TO APPLICATION VALVE
TUBING
TO MAIN RESERVOIR
MOTOR STARTING SWITCH
RECEIVER
MECHANISM CASE
TO DISTRIBUTION CABINET

Figure 77. Typical arrangement of apparatus, diesel-electric locomotive.

FEATURES

Among the more important features of the G-R-S intermittent inductive train control system are the following:

1. No physical contact between wayside and locomotive equipment.
2. Wayside inductor circuits require no energy. Inductors are passive units controlled by simply opening or closing a 2-wire circuit.
3. Opening of inductor winding, or break in inductor control circuit, automatically leaves inductor in restrictive condition.
4. Locomotive equipment operates on closed circuit principles. All relays, also the electro-pneumatic valve, must be held energized. Circuit or power failure results in automatic brake application.

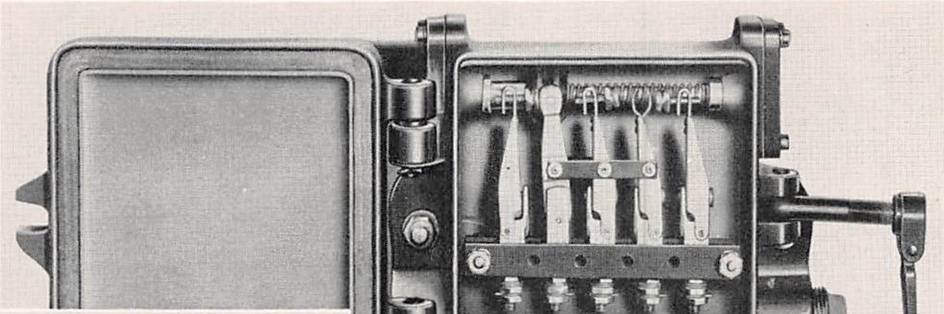


Figure 79. Reset contactor, cover open.

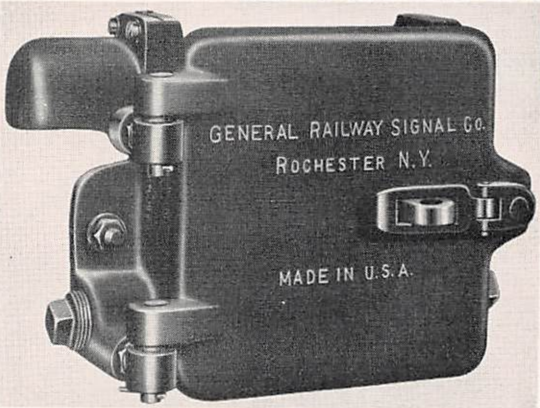

GENERAL RAILWAY SIGNAL Co.
ROCHESTER N.Y.
MADE IN U.S.A.

Figure 78. Reset contactor, cover closed.

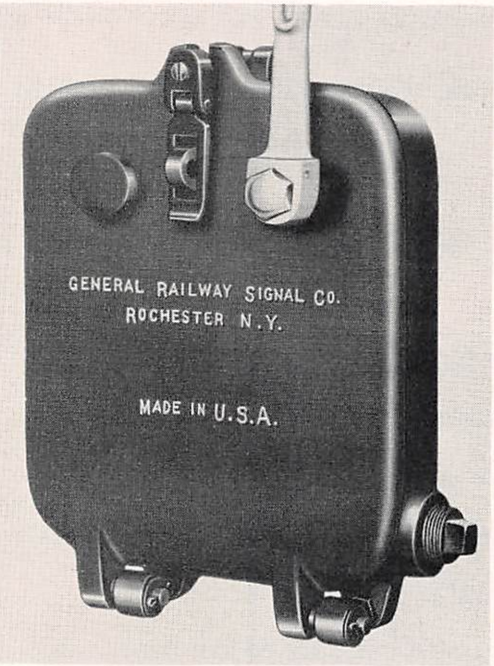

GENERAL RAILWAY SIGNAL Co.
ROCHESTER N.Y.
MADE IN U.S.A.

Figure 80. Acknowledging contactor, cover closed.

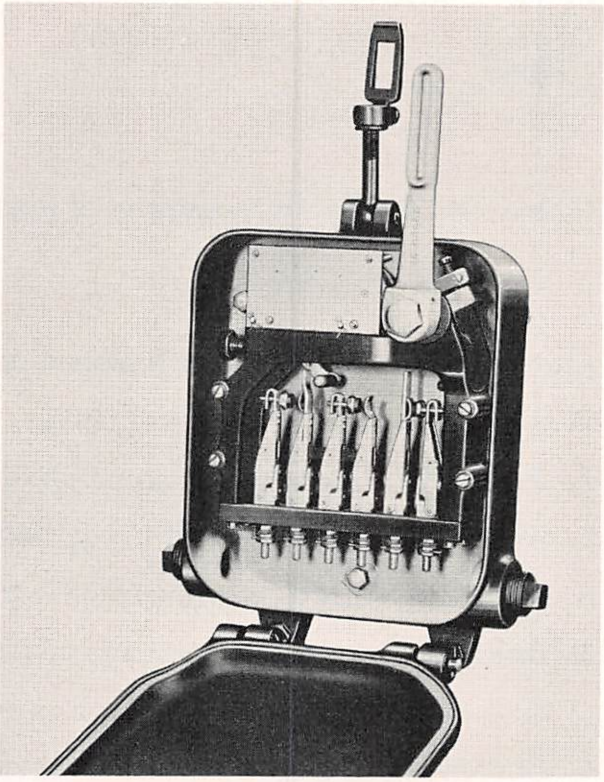


Figure 81. Acknowledging contactor, cover open.

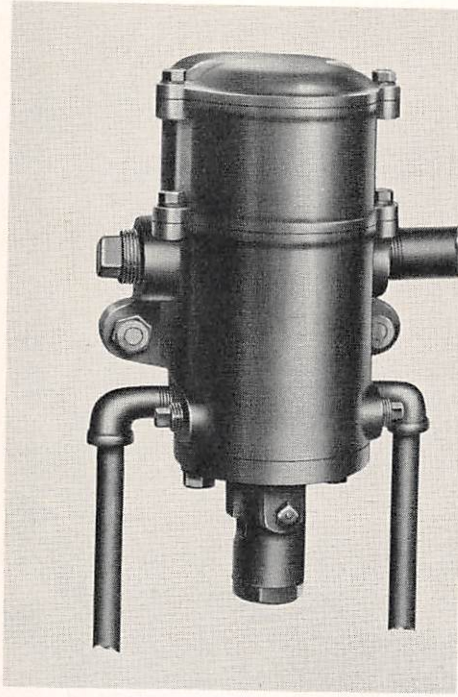


Figure 82. Electro-pneumatic valve.

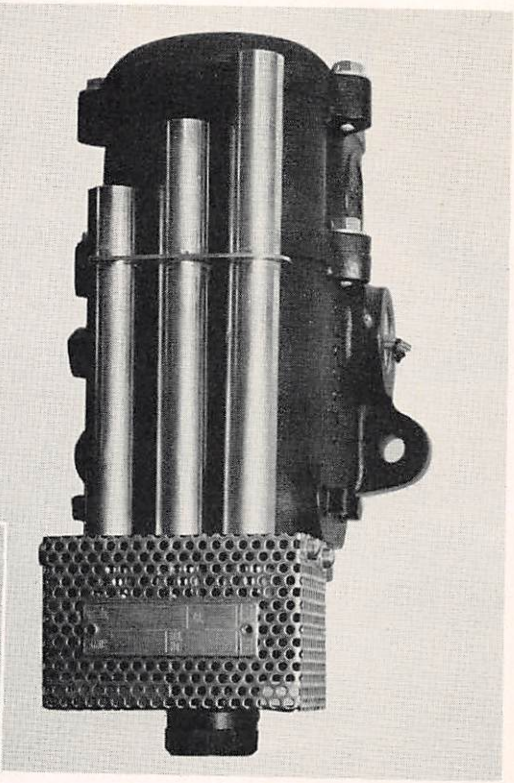


Figure 83. Whistle and whistle valve.

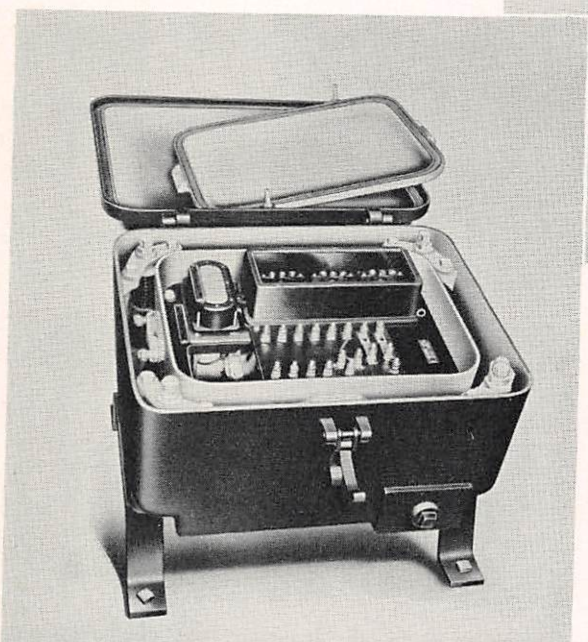
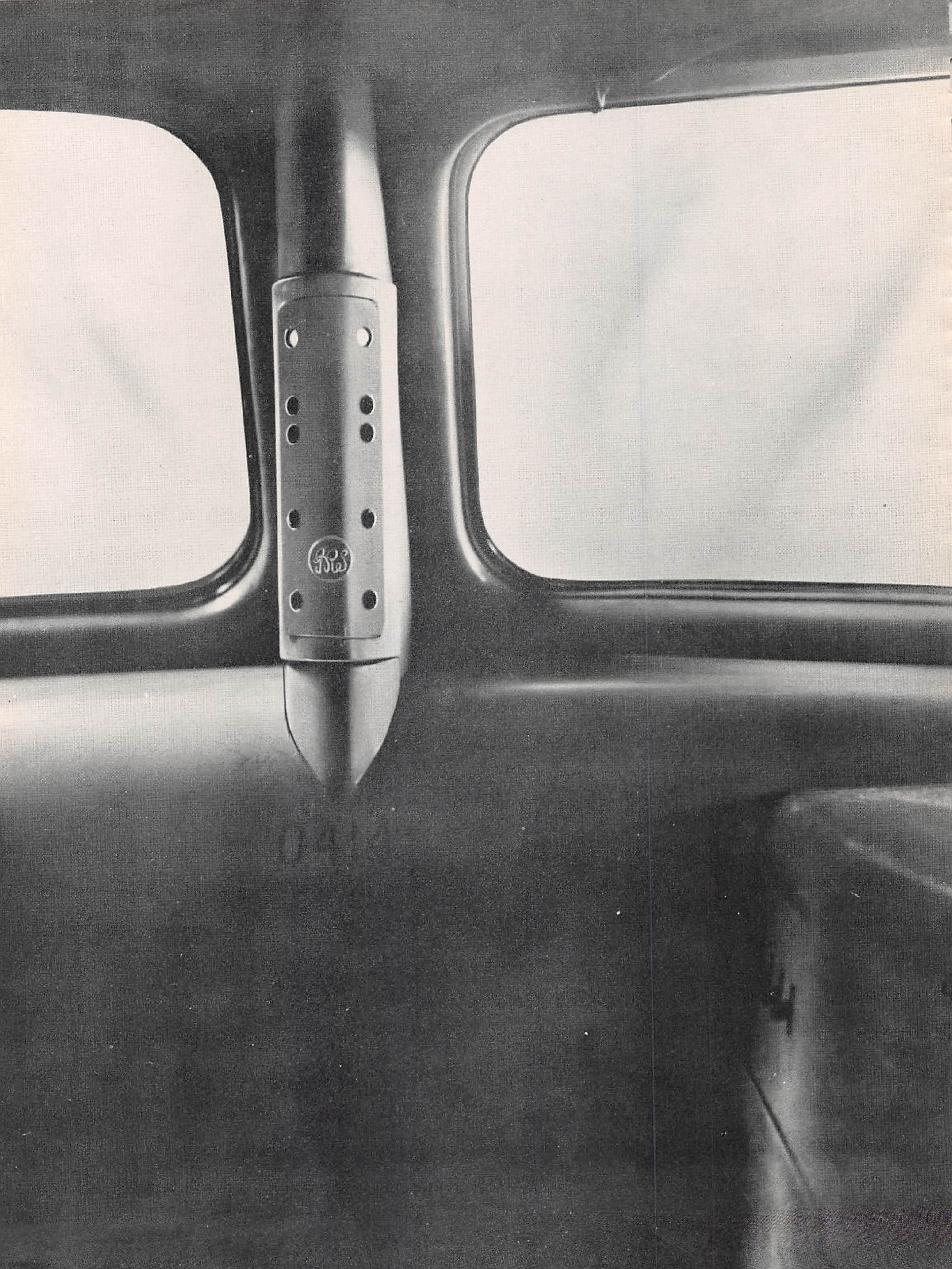


Figure 84. Mechanism case, showing shock and vibration absorbing mounting.



CAB SIGNALS AND CONTINUOUS INDUCTIVE TRAIN CONTROL

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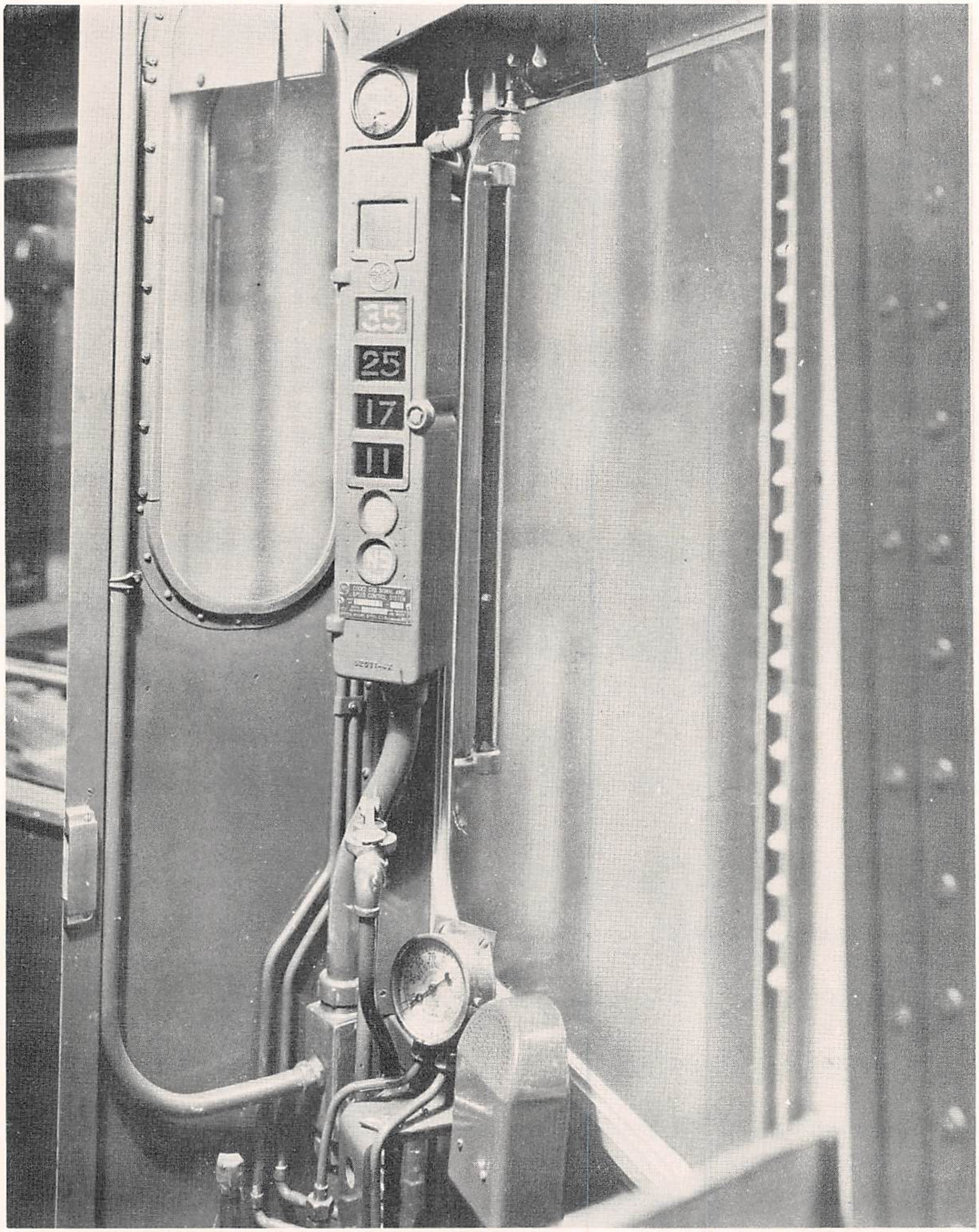


Figure 85. Four-aspect cab signal used with continuous automatic speed-control system. The numerals indicate the maximum speed permitted for each aspect without automatic brake application.

CAB SIGNALS AND CONTINUOUS INDUCTIVE TRAIN CONTROL

GENERAL DESCRIPTION

The G-R-S coded cab signal system extends the utility of automatic block signals by providing a display of the signal aspect for each block directly in the locomotive cab. To add to the effectiveness of this visual display, the system includes a warning whistle which sounds each time the signal aspect becomes more restrictive and continues to sound until silenced by the manual operation of an acknowledging contactor. The engineman's attention is thus immediately attracted to a less favorable aspect, even if his eyes happen to be directed elsewhere at the time it occurs, and his awareness of the restriction is verified by his acknowledging action.

Since the signal aspect is continuously visible, the engineman is able to proceed at maximum permissible speed, even when fog, snow, smoke, or other conditions limit outside visibility. The engineman is also enabled to increase speed promptly when a restrictive aspect changes to a more favorable one, thus saving the time that would otherwise be lost in proceeding to the next wayside signal at an unnecessarily low speed. Because of these operating advantages, cab signals serve to increase average speeds, provide greater track capacity, and help maintain on-time performance.

Cab signals may be used in conjunction with fixed wayside signals, as indicated in Figure 86, or they may be used alone, without wayside signals. In either case, the system is designed to display the various restrictive aspects of the cab signal over a sufficient number of blocks in approach to an obstruction to provide adequate braking distance.

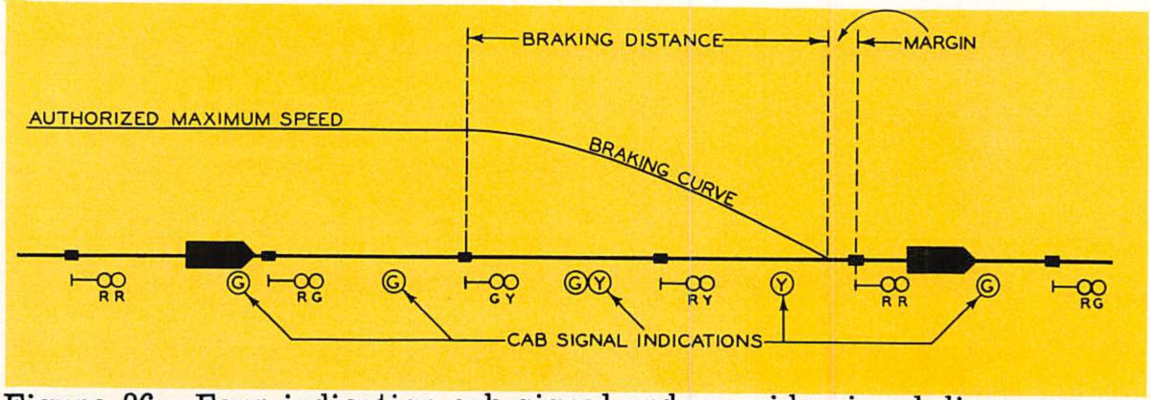


Figure 86. Four-indication cab signal and wayside signal diagram.

WAYSIDE CIRCUITS AND EQUIPMENT

The arrangement of wayside circuits for cab signaling may be varied to fit local conditions, and depends to a large extent on whether or not wayside signals are used in conjunction with the cab signals. The basic requirement is the provision of a code transmitter, Figure 87, for each block which feeds uniformly spaced impulses of current into the track circuit. The repetition rates of these current impulses constitute codes which control the cab signal aspects. The particular code fed into each track circuit is automatically determined by block conditions in advance. Commonly used codes are: 180 times a minute for ''proceed'' (green); 120 times a minute for ''approach medium'' (yellow/green); 75 times a minute for ''approach'' (yellow). Absence of code currents in the rails, resulting from a train shunt, or from any other cause, produces the most restrictive aspect, which may be red, red/yellow, lunar white or any aspect required by the individual railroad's rules.

You will note that this arrangement is similar to that used for control of wayside signals through coded track circuits, and, if desired, the two systems - cab signals and coded track circuit control of wayside signals- may be readily combined.

LOCOMOTIVE EQUIPMENT

Figure 88 shows in diagrammatic form the organization of the locomotive cab signal equipment. The receivers are mounted on the locomotive so that they are carried a few inches above the rails and just ahead of the leading wheels, Figure 89. These receivers are actually coils, wound on steel cores, in which voltages are developed by electro-magnetic induction from the rail currents, as shown in Figure 90*. The voltage pulses from

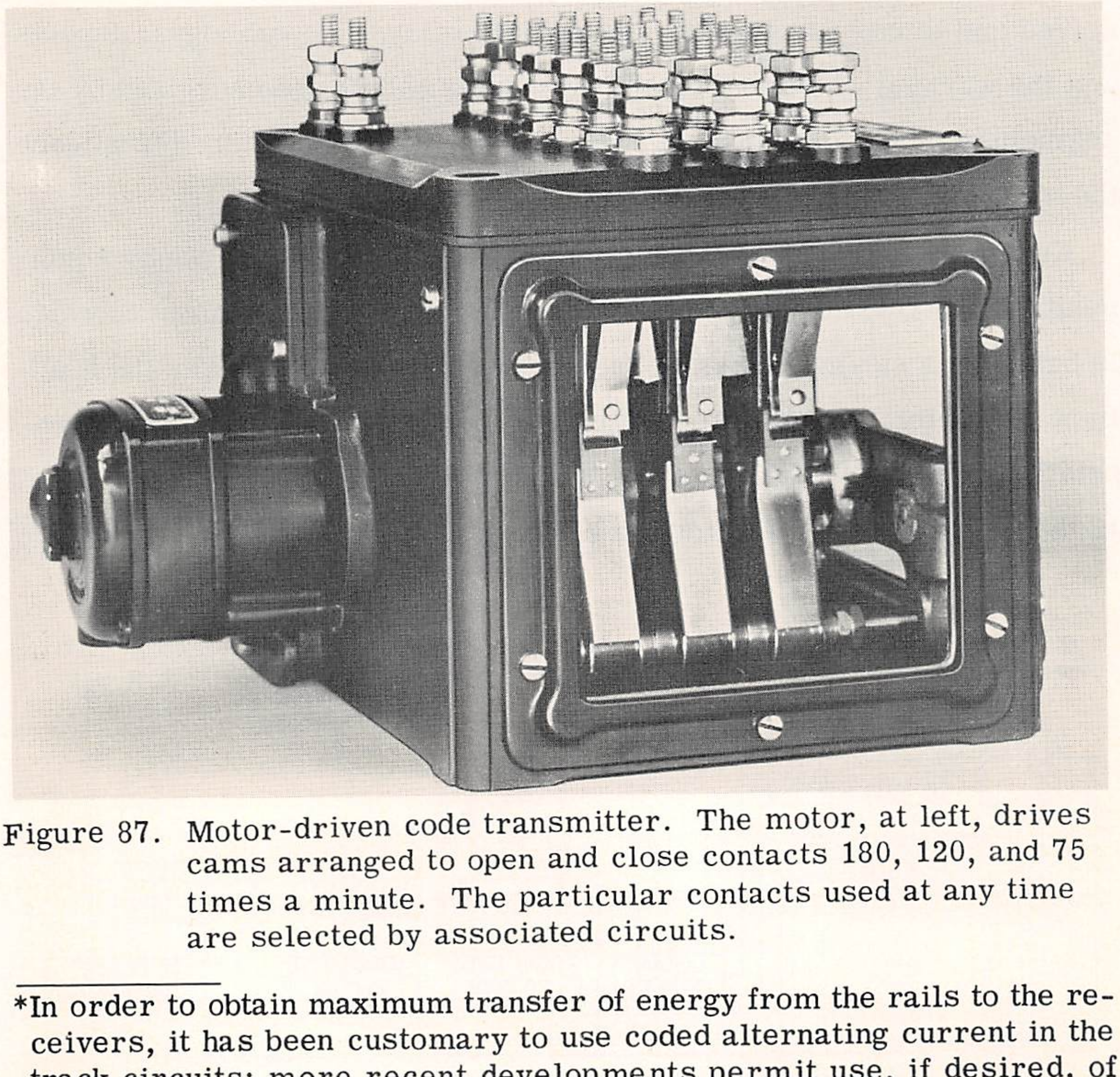


Figure 87. Motor-driven code transmitter. The motor, at left, drives cams arranged to open and close contacts 180, 120, and 75 times a minute. The particular contacts used at any time are selected by associated circuits.

---

*In order to obtain maximum transfer of energy from the rails to the receivers, it has been customary to use coded alternating current in the track circuits; more recent developments permit use, if desired, of coded direct current in the track circuits. The locomotive equipment designed for use with d-c. codes also operates on a-c. codes without any adjustment or switching.

the receivers are amplified in the amplifilter, a combined filter and electronic amplifier, the output of which drives the master relay, causing the latter to pulse in synchronism with the code impulses in the track. The master relay, as it pulsates, excites a transformer by pole-changing, at code rate, a d-c. voltage fed to the transformer primary. The resultant a-c. output of the transformer secondary is fed to the decoder unit, which utilizes resonant circuits to identify the code rate being received and to control, through appropriate relays, the cab signal aspects and the warning whistle. The acknowledging relays are energized by the engineman through the manual contactor previously mentioned to silence the warning whistle after it sounds.

Energy requirements for operation of the locomotive cab signal equipment are obtained from the local locomotive supply. In Figure 88, which is based on a steam locomotive installation, this is indicated as the headlight generator. For diesel-electric or electric locomotives, the appropriate locomotive source would be substituted for the headlight generator. High voltage for the electronic amplifier is supplied by the dynamotor

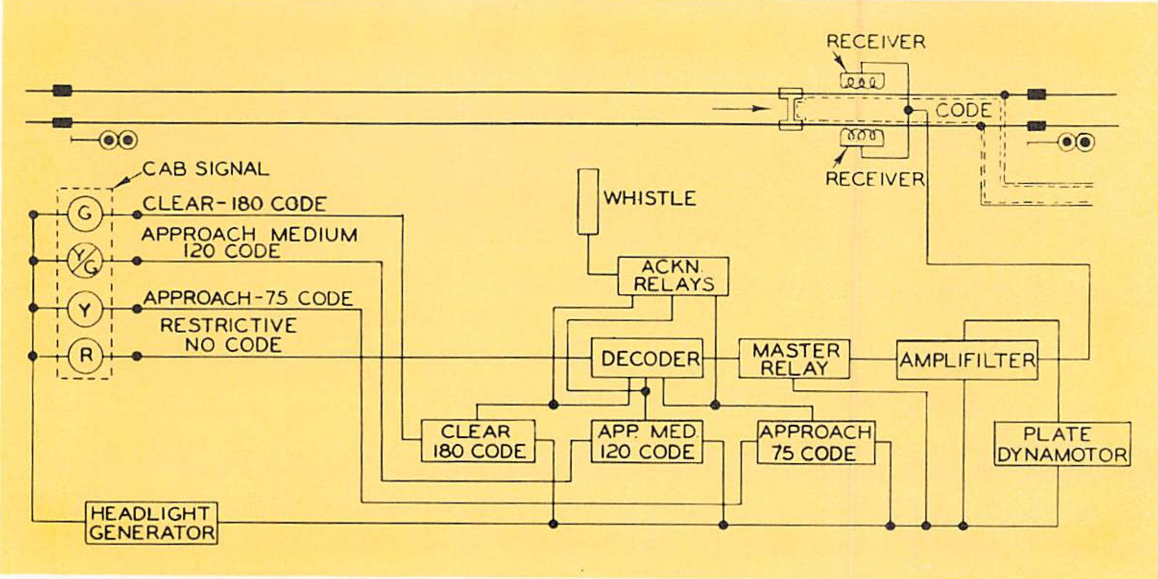

RECEIVER
CODE
RECEIVER
CAB SIGNAL
G
Y/G
Y
R
CLEAR-180 CODE
APPROACH MEDIUM 120 CODE
APPROACH-75 CODE
RESTRICTIVE NO CODE
WHISTLE
ACKN. RELAYS
DECODER
MASTER RELAY
AMPLIFILTER
CLEAR 180 CODE
APP. MED. 120 CODE
APPROACH 75 CODE
PLATE DYNAMOTOR
HEADLIGHT GENERATOR

Figure 88. Organization of locomotive equipment for four-indication cab signal system.

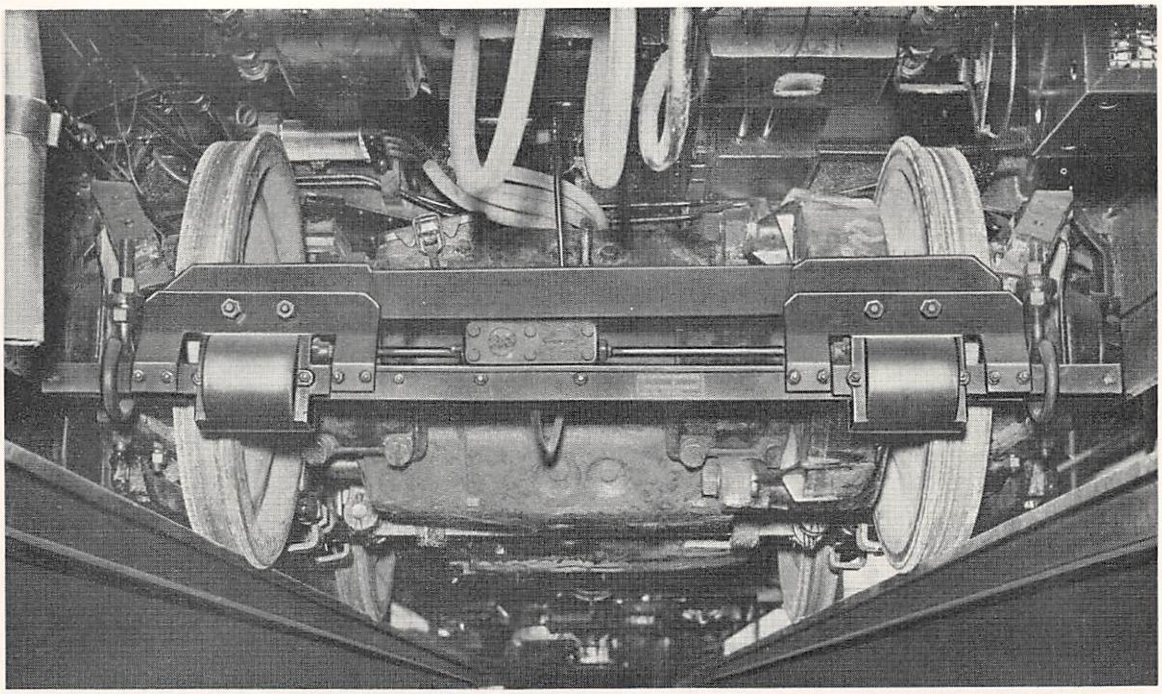


Figure 89. Receiver mounted ahead of leading wheels of multiple-unit electric train.

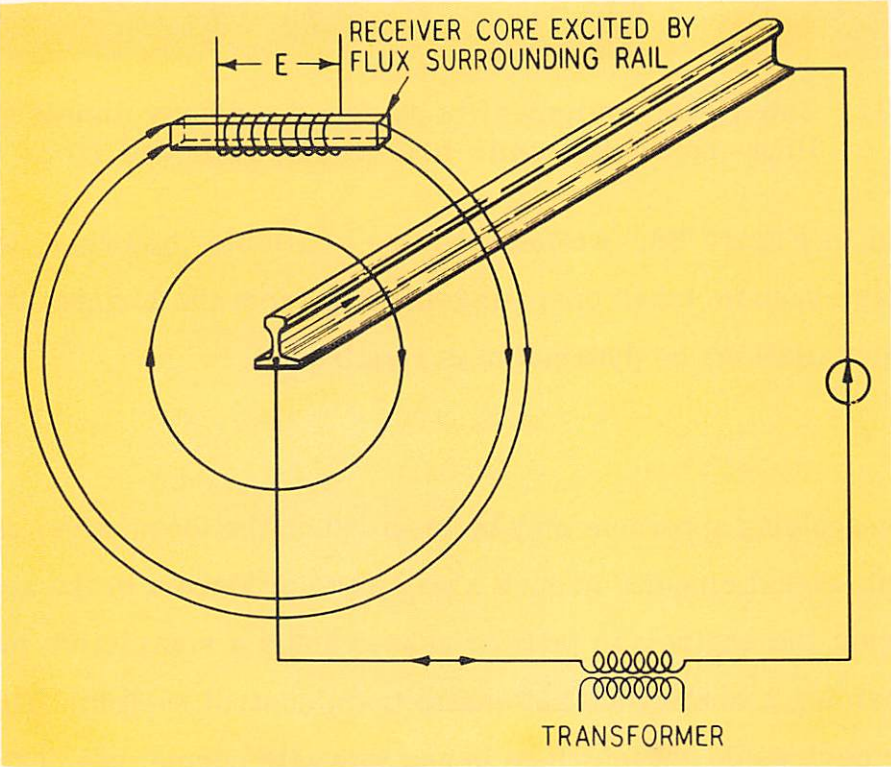

RECEIVER CORE EXCITED BY FLUX SURROUNDING RAIL
E
TRANSFORMER

Figure 90. Magnetic flux surrounding rail induces voltage in receiver coil.

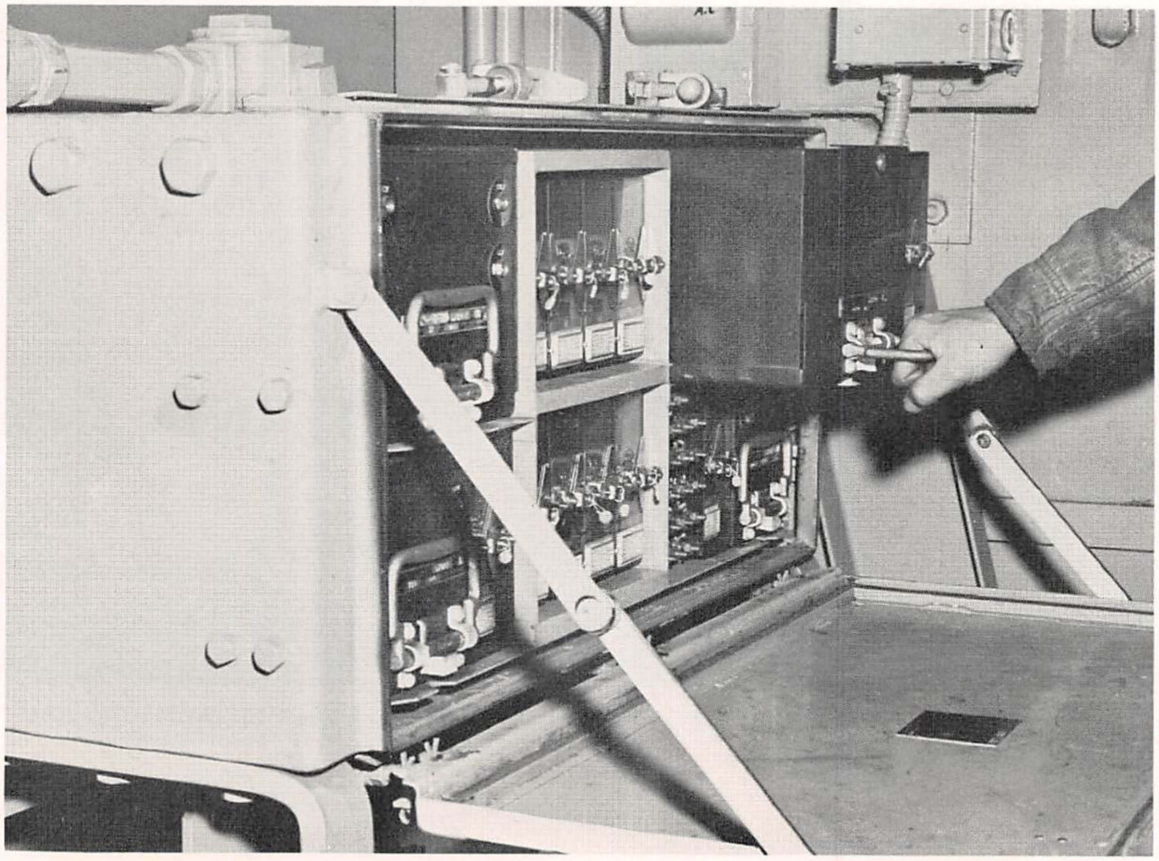


Figure 91. Cab signal equipment is designed for easy maintenance. Plug-connected units are readily removed from case.

indicated in Figure 88. Amplifiers are available, however, which use low-voltage vacuum tubes operating directly from the locomotive supply. In such installations no dynamotor is required.

CONTINUOUS INDUCTIVE TRAIN CONTROL

Brake-applying apparatus may be installed on the locomotive, controlled by the cab-signal circuits in such a way as to produce a brake application in the event the engineman fails to acknowledge a restrictive indication, thus providing a continuous automatic train control system. The brake-applying devices do not interfere in any way with normal use of the brakes so long as the engineman makes proper acknowledgment, since he proves,

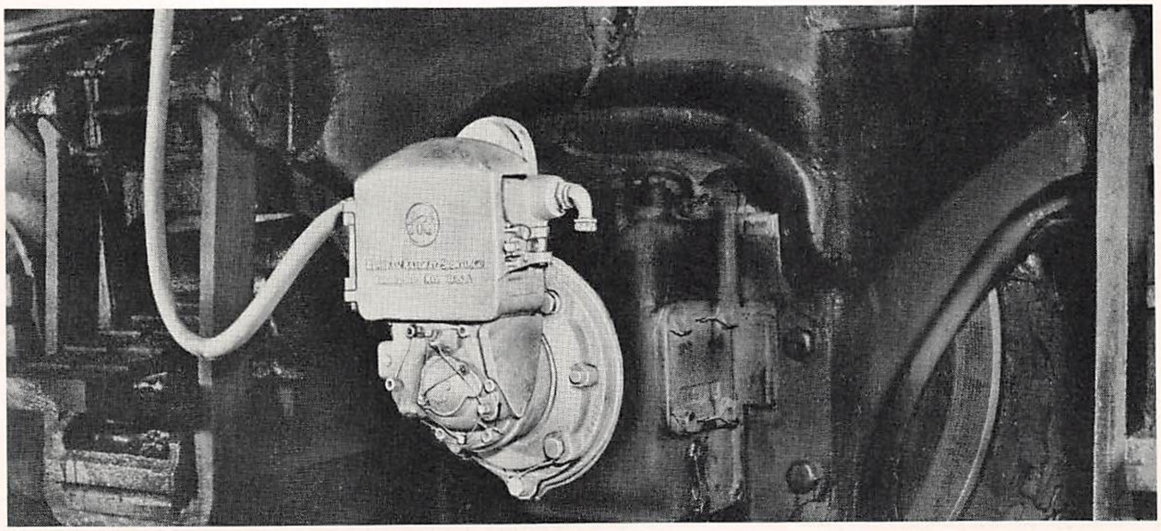
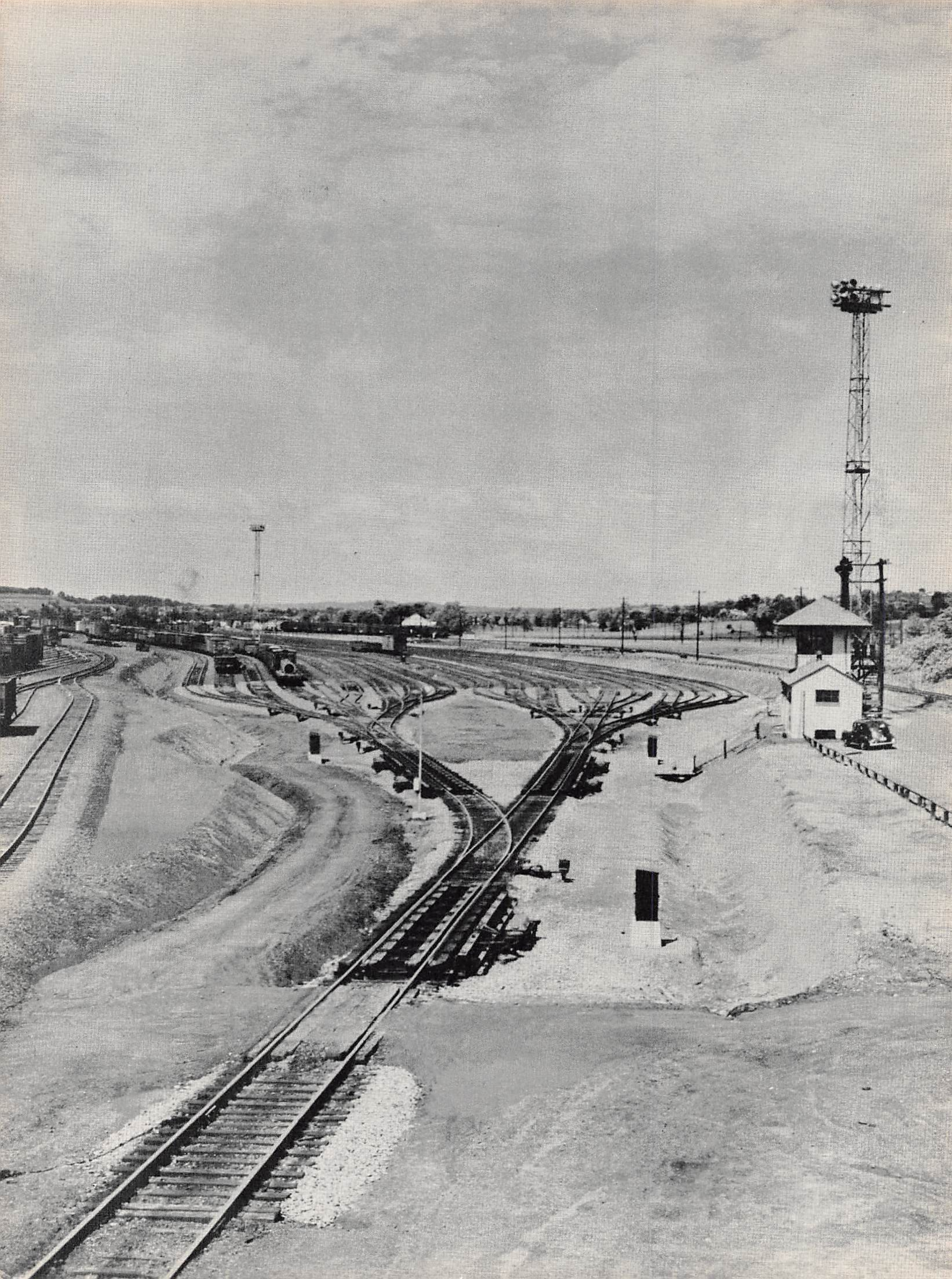


Figure 92. Speed governor, suitable for use with continuous speed-control system, mounts directly on journal box.

by that action, that he is alert to the restrictive condition. If he fails to acknowledge, however, the resulting automatic brake application cannot be released until a reset contactor has been operated. Reset circuits may be arranged so that it is not possible for an engineman to reset the system, and thereby regain ability to release the brakes, until the train has been stopped or until a specified time interval has elapsed after the automatic brake application.

By combining the cab signal and brake applying apparatus with a speed governor, Figure 92, an automatic speed-control system may be obtained. The speed governor is equipped with a series of contacts which may be adjusted to open and close circuits at desired train speeds, so that an automatic brake application will occur if the train speed exceeds a pre-established value for each signal aspect. If such an automatic application occurs, the brakes cannot be released by the engineman until the train speed has been reduced to the value permitted for the signal aspect governing the block.



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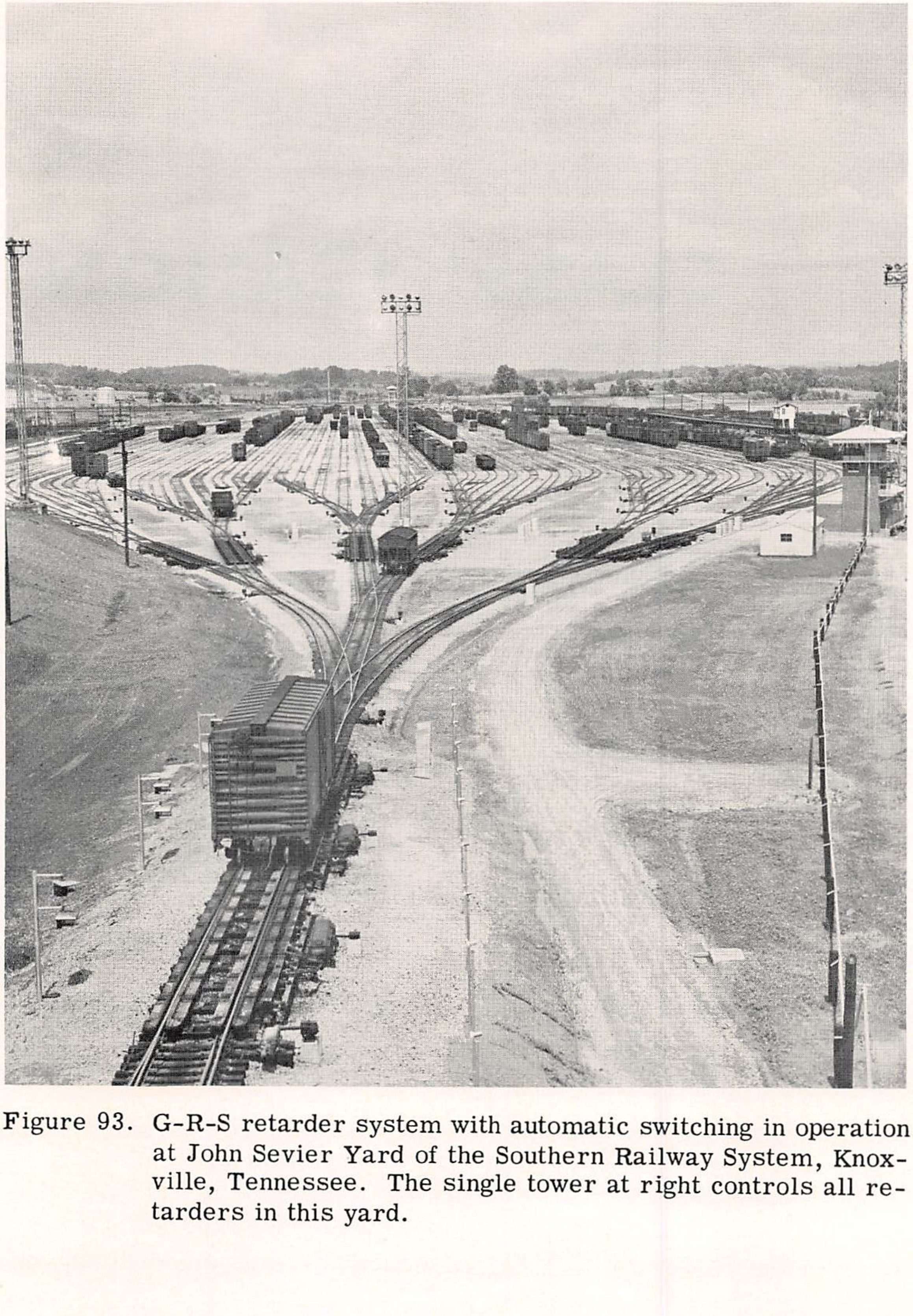

Figure 93. G-R-S retarder system with automatic switching in operation at John Sevier Yard of the Southern Railway System, Knoxville, Tennessee. The single tower at right controls all retarders in this yard.

CAR CLASSIFICATION

BASIC ELEMENTS

The G-R-S retarder system provides an efficient, economical method of handling cars in classification yards of the gravity type (hump yards). The particular design of a G-R-S retarder system varies from yard to yard, depending upon location, type and weight of cars to be handled, number of tracks, volume of classification work, etc., but basic elements in all installations are the G-R-S car retarder for controlling the speed of cars, and the use of power-operated switches for routing cars to classification tracks. The latter item, power switching, may be manually controlled, or it may be automatic in operation, as described later.

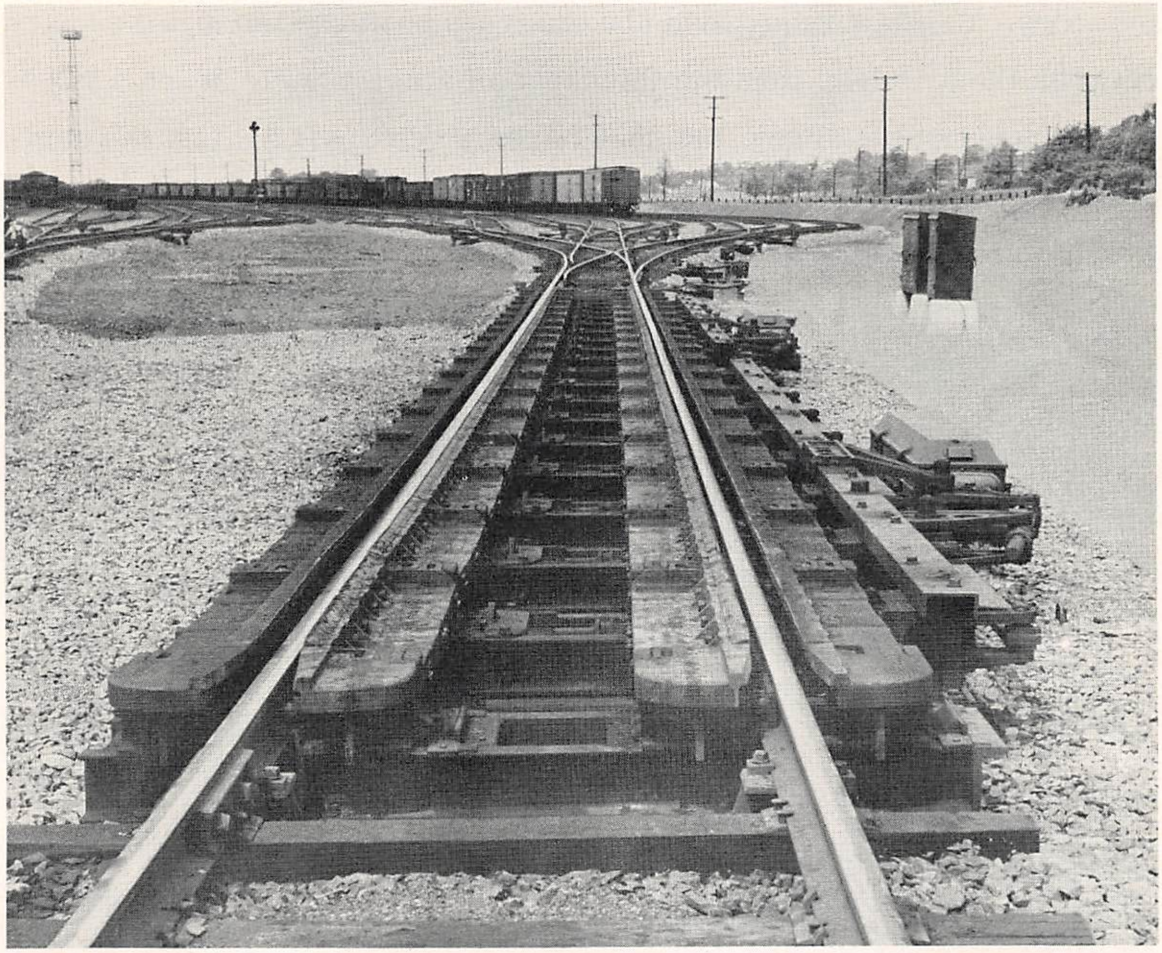

Figure 94. Typical G-R-S car retarder installation. The equipment cases at right house relays, contactors, etc., for control of the retarders.

ELECTRIC CAR RETARDERS

The G-R-S car retarder, Figure 94, is a rail brake, electrically controlled, by means of which the speed of cars rolling down to the classification tracks may be regulated by an operator in a tower. The braking effect of the retarder is obtained by means of heat-treated alloy steel shoes mounted on each side of the rails, as shown in simplified form, for one rail, in Figure 96. A reversible motor and an associated gear train, part of the mechanism shown in Figure 95, rotate the drive gear. Counterclockwise rotation of the drive gear moves the shoes toward each other, as shown by the arrows adjacent to the shoes. Clockwise rotation separates the shoes. To obtain retardation, the shoes are positioned so that the space between them is less than the thickness of a car wheel. When a wheel moves between the shoes, the shoes are forced apart against the compression of the spring. The resultant frictional forces between the shoes and the car wheel serve to retard the car.

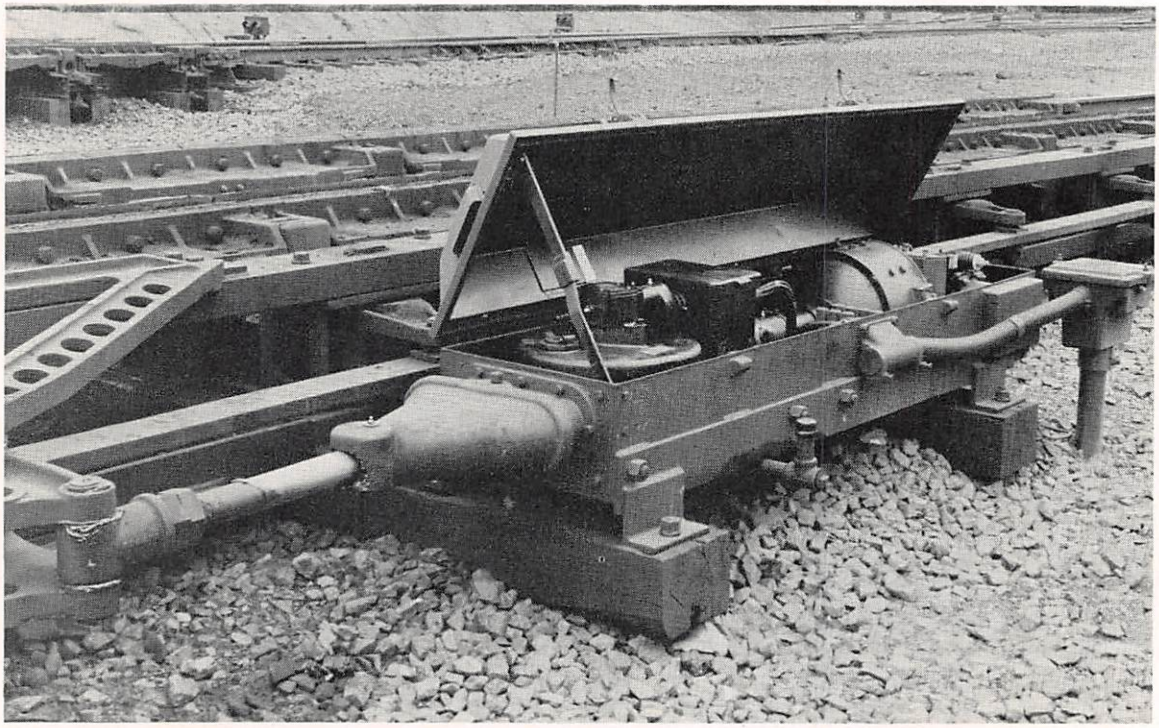

Figure 95. Mechanism of G-R-S car retarder.

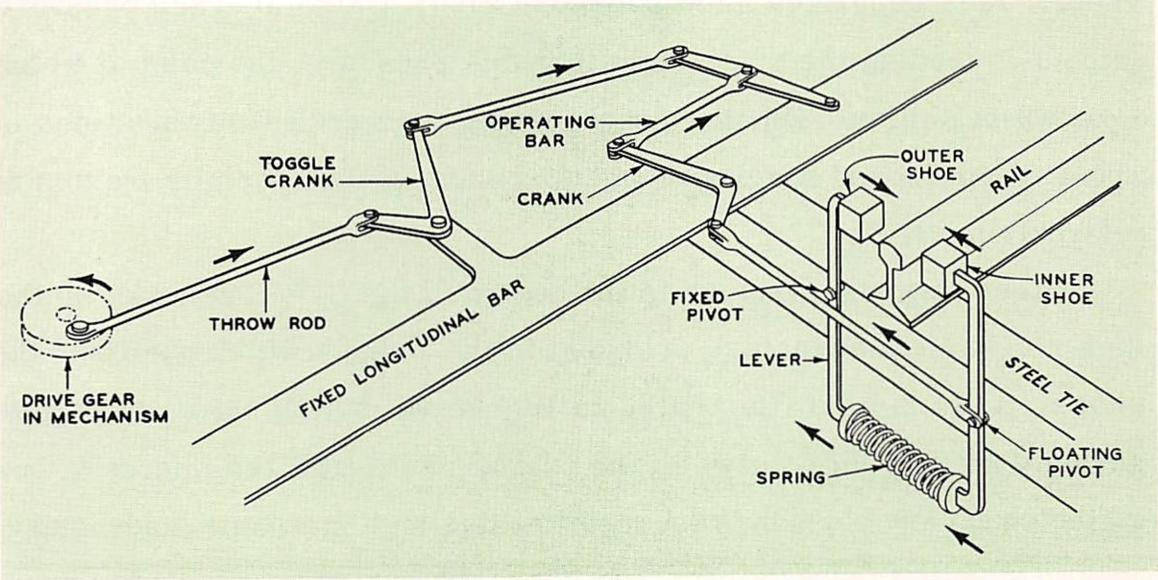
OPERATING BAR
TOGGLE CRANK
CRANK
OUTER SHOE
RAIL
INNER SHOE
FIXED PIVOT
THROW ROD
FIXED LONGITUDINAL BAR
LEVER
STEEL TIE
DRIVE GEAR IN MECHANISM
FLOATING PIVOT
SPRING

Figure 96. Simplified diagram of linkage to position retarder shoes.

The amount of retardation obtained depends upon the position of the retarder shoes when there is no wheel between them. The closer together in their original position, the more the spring is compressed when the shoes are separated to car-wheel width, and the greater the braking force exerted by the retarder.

The retarder mechanism provides four positions of the shoes for four degrees of retardation, and an open position in which the shoes do not touch the wheels. In the maximum closed position, the G-R-S retarder is capable of stopping and holding a car on the hump grade; in the open position, the retarder has no effect on the car. Intermediate positions provide intermediate degrees of retardation.

An important feature of the G-R-S car retarder is the design of the linkage between the inner and outer shoes at each rail. As shown in Figure 96, a combination of fixed and floating pivots is used to adjust the spacing between shoes, an arrangement which makes the pressure exerted by the shoes equal on both inside and outside surfaces of the wheel. This equalized shoe pressure gives a high average pressure without exceeding the maximum allowable pressure, the point at which a car wheel is lifted. Equalized shoe pressure, regardless of variations in wheel thickness and spacing of wheels on axles, thus permits maximum retardation effect.

Another important feature in the design of the G-R-S retarder is the high mechanical advantage provided in the linkage which positions the shoes. This is also illustrated in Figure 96, which shows the toggle action which occurs between the toggle crank and the operating bar as the shoes are closed. As a result of this high mechanical advantage, only moderate torque is required of the drive motor, even when compressing the springs directly, as when the retarder is adjusted to a higher degree of retardation with a car in the retarder.

A further design refinement in the G-R-S retarder is the articulation of the beams which support the retarder shoes. This permits adjacent springs to share the retardation load and at the same time eliminates the possibility of binding caused by variations in track level. The G-R-S retarder readily adapts itself to considerable vertical misalignment in the track, and, in fact, is frequently installed on vertical curves. Articulation provides the additional advantage that any number of retarder units may be assembled in line to produce a continuous retarding surface with most economical use of track space.

G-R-S retarders are available in units of 5-1/2 feet of rail length, for application to one rail or both, or for combinations of single- and double-rail retardation, and as many as nine units of double-rail retarder (49-1/2 feet) may be operated from one mechanism. For most efficient utilization of a given total length of retarders, and for flexibility of control, a set of retarders is usually located just below the crest of the hump, with additional sets of retarders on the tracks which lead to each group of classification tracks. This arrangement permits preliminary retardation of all cars by the hump retarders, with final control at the retarders located ahead of the classification track groups. A typical retarder layout of this kind is shown in Figure 97.

CONTROL OF RETARDATION

The car retarders are controlled by an operator at a control machine, Figure 98, located in a tower from which the operator has a clear view of the track and the retarders. The control machine has levers which enable the operator to set each retarder to the position he desires. The machine also has other levers which permit the operator to operate the switches in the yard.

Since rolling resistance of cars varies with type of car, condition of journals, wheel wear, weight, temperature, wind conditions, etc., the grades in the yard must ensure that the hardest rolling car will roll through the yard to the desired position on a classification track. The function of the retarder operator is to control the car retarders so that freer rolling cars, which would otherwise acquire excessive speed, are

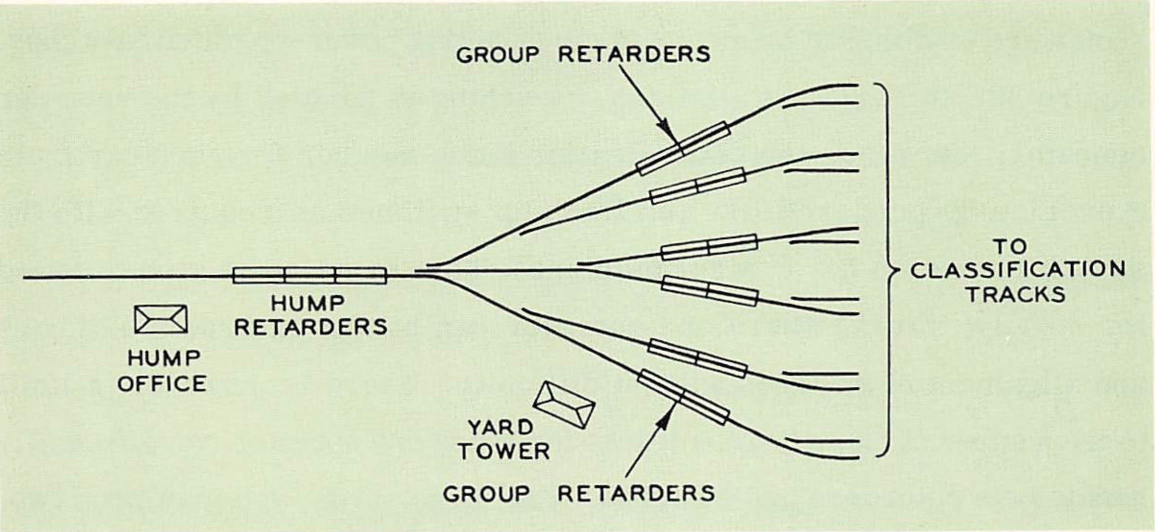

Figure 97. Typical arrangement of retarders.

sufficiently slowed by the retarders so that they, too, enter the classification tracks at proper speed.

The usual practice is for the operator to set the retarders at one of the four available closed positions, which in his judgment, is proper for the weight and type of each car, and to open the retarders when the car has been slowed to the desired speed. Should there be an error in judgment as to the correct setting, the retarder can be re-positioned to any other degree of retardation, lower or higher, while the car is in the retarder, without overloading the drive motor or overstressing the mechanism.

Note how the whole yard layout appears diagrammatically on the control machine panel shown in Figure 98, with all controls for retarders and switches within easy reach, and in their proper respective locations on the track layout. This makes it simple for the operator. He doesn't have to memorize the relationship of the control levers to the actual yard layout.

An important element in the efficient operation of a hump yard is the method by which the routes are lined up from the hump to the individual classification tracks. In yards equipped with the G-R-S retarder system, routes are established by means of quick-acting power-operated switches, Figure 99. In some installations, switching is handled by the retarder operator, who reads the classification track number for each car from a previously prepared list and lines up switches as required with the switch levers on his control machine. This practice is still followed for smaller yards, where one operator can handle retardation of cars and alignment of switches without difficulty. There is, however, a limit to the number of classification tracks for which one operator can efficiently handle both retarders and switches. For large yards, you may need two, three, or more operators, each in a separate tower, to handle the volume of work.

AUTOMATIC SWITCHING

A more recent development is G-R-S automatic switching for car retarder yards. G-R-S automatic switching relieves the retarder operator of the responsibility for lining up switches, and lets him concentrate entirely on retarding cars. As a result, one operator and one tower are sufficient for yards of practically any size. Moreover, switching errors are reduced. The combined effect of these two factors - a single tower with one operator and reduction in switching errors - is a substantial gain in efficiency and economy.

When automatic switching is used, you have an additional control panel,

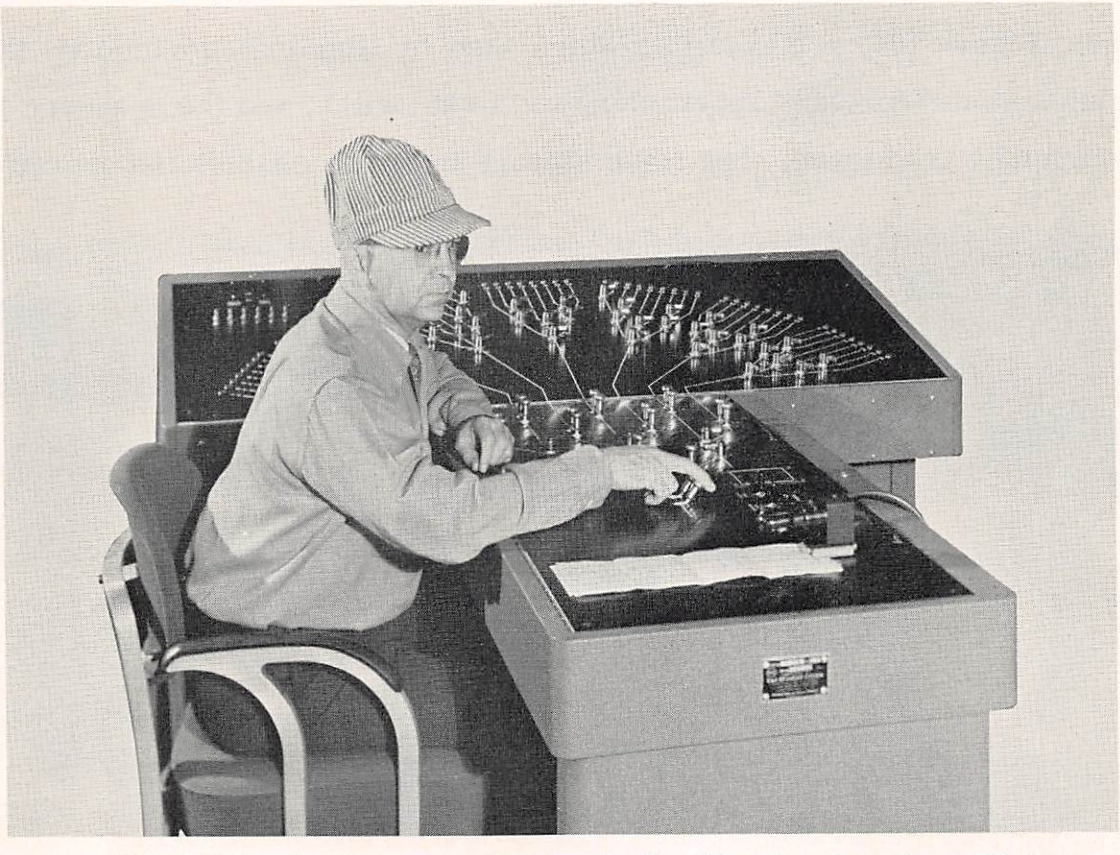

Figure 98. This retarder operator controls all retarders in a 58-track classification yard. Cars are normally routed by automatic switching, but switches can be manually controlled, when required, by means of the levers visible on the track plan.

Figure 100, equipped with numbered pushbuttons, one for each classification track. The complete route for each car, or cut of cars, is set up by merely pushing the button whose number corresponds to the desired classification track. Thereafter, switch throwing for each route is entirely automatic - the switches line up ahead of the car as it travels along. To provide maximum utility, route storage arrangements are incorporated in the circuits which permit the operator to push several buttons in succession for following cars, even before the leading car reaches the first switch past the hump. Such stored routes are automatically fed out into the system as the corresponding cars move over the first switch.

To facilitate the work of the pushbutton operator, route storage indicators, Figure 101, are available which show by illuminated numerals the routes stored for cars approaching the first switch, and the sequence in which they are stored. The route storage indicator enables the operator

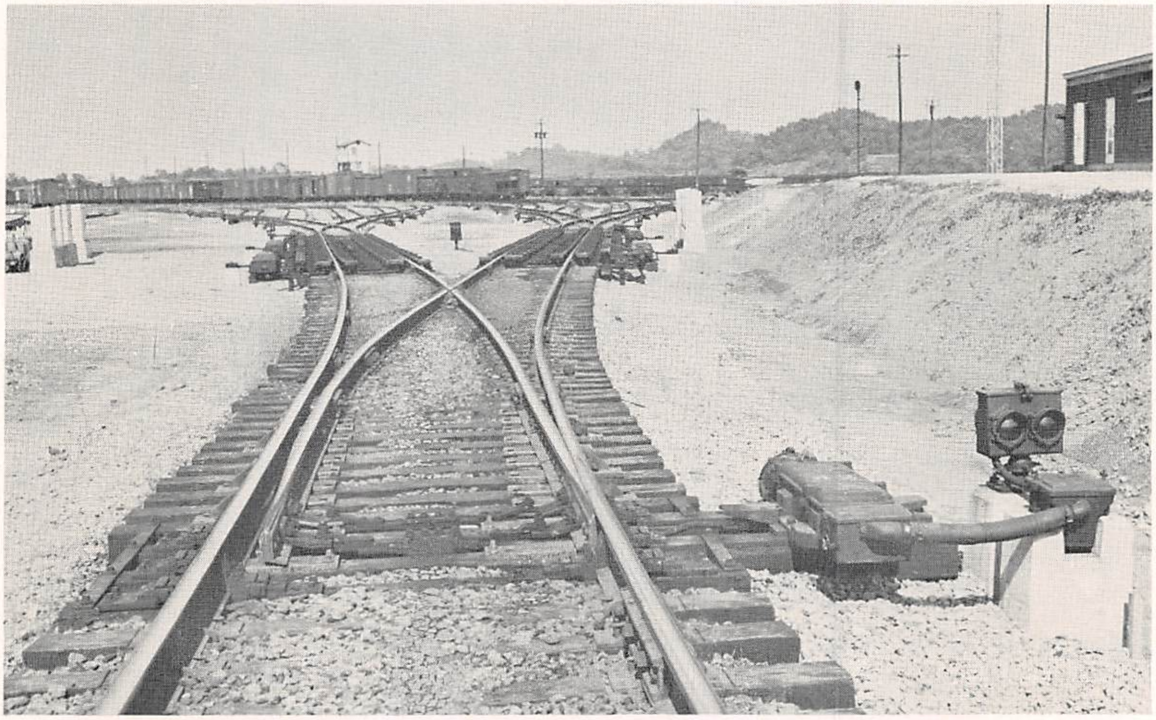

Figure 99. Typical switch layout, using a G-R-S quick-acting Model 6 electric switch machine, and a G-R-S Type P signal.

to check that he has pushed the proper buttons. Should an error occur, means are provided for cancelling routes stored for cars which have not yet reached the first switch.

It is customary to install the pushbutton panel for automatic switching in a separate machine, located at the hump, where it is operated by the hump conductor. It is also possible, however, to combine the pushbutton panel with the retarder control machine, Figure 102, so that the tower operator can handle both routing and retardation.

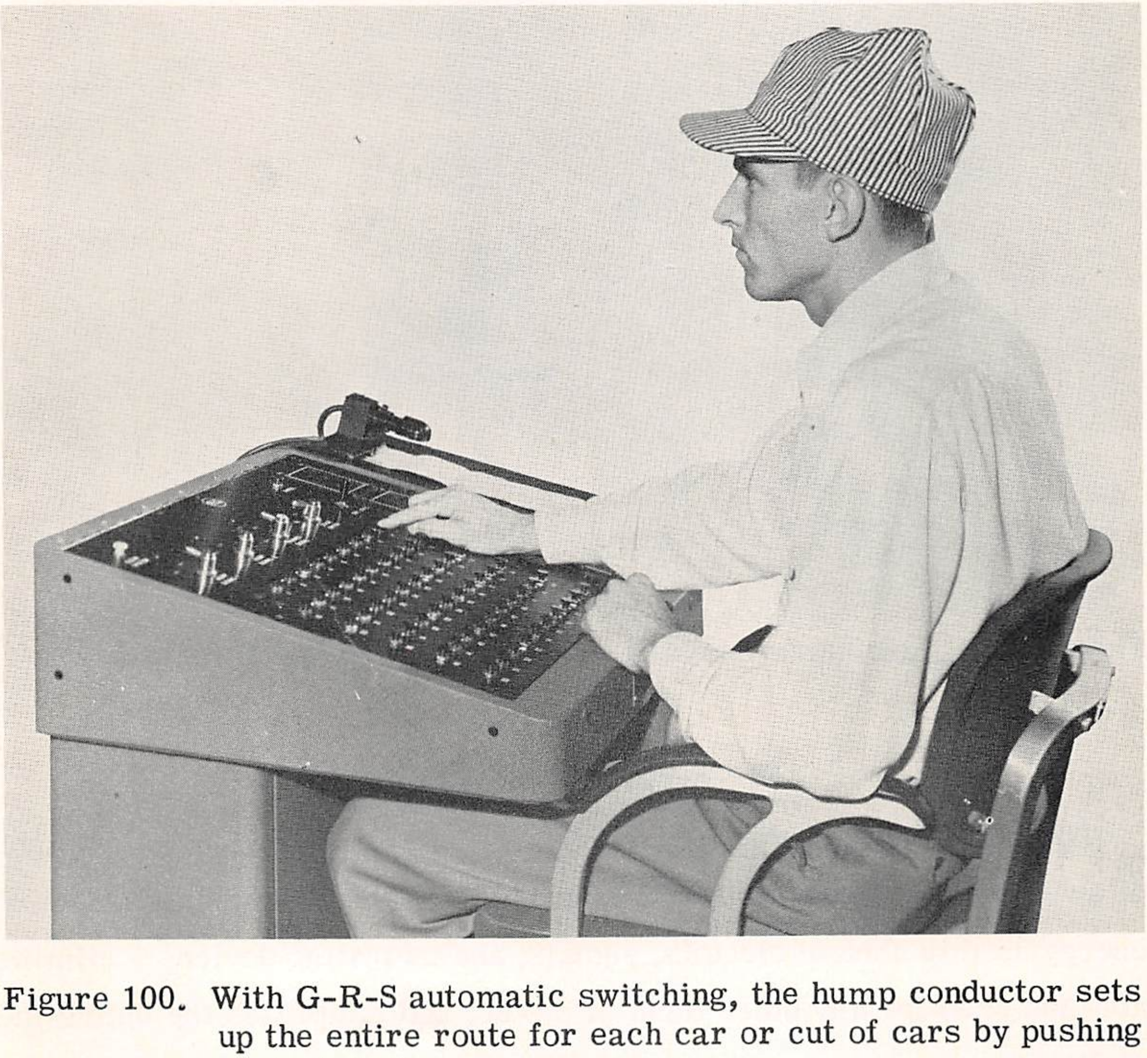

Figure 100. With G-R-S automatic switching, the hump conductor sets up the entire route for each car or cut of cars by pushing a single button.

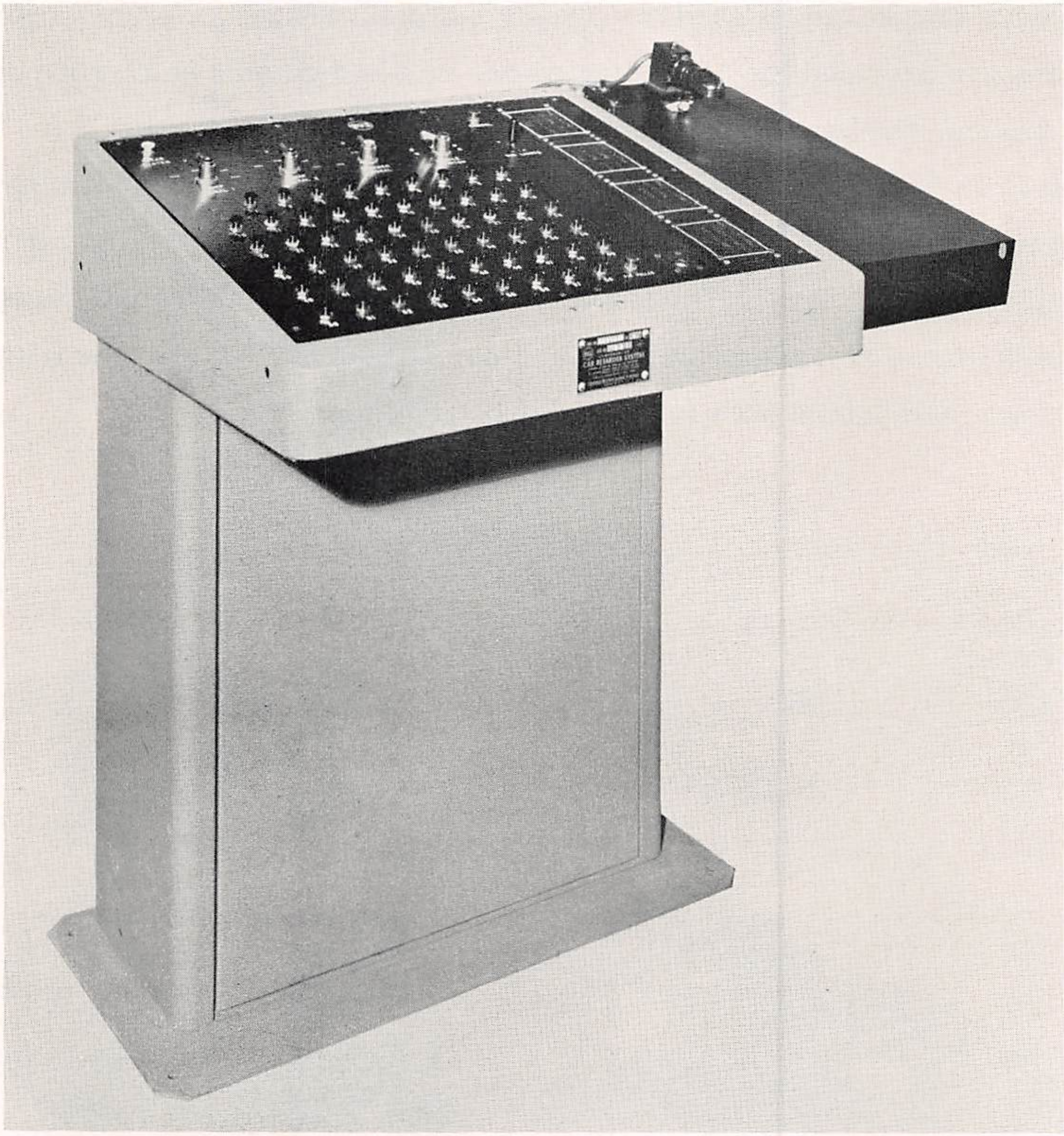

Figure 101. Pushbutton machine, showing route storage indicators.

ALL-ELECTRIC OPERATION

The G-R-S retarder system is all-electric in operation. Alignment of switches and control of retarders by electricity - the same form of energy used in control circuits, signals, and indicating devices - eliminates the need for any other form of power, and simplifies the entire installation.

Moreover, it should be noted that the G-R-S car retarder requires energy only for the purpose of changing the position of the retarder shoes - i.e., for changing the degree of retardation. Except when such changes are being made, the retarder shoe position is maintained fixed by the mechanism, which is locked in place by means of a magnetically controlled brake. Since the actual retardation forces are supplied by springs, no energy is required for retardation purposes. Energy consumption of the entire retarder system is therefore low, normally not exceeding 70 watt-hours per car classified. This includes operation of the retarders, switch machines, switch signals, track circuits and indicating lights on the operator's control machine.

All-electric operation in retarder yards provides definite advantages,

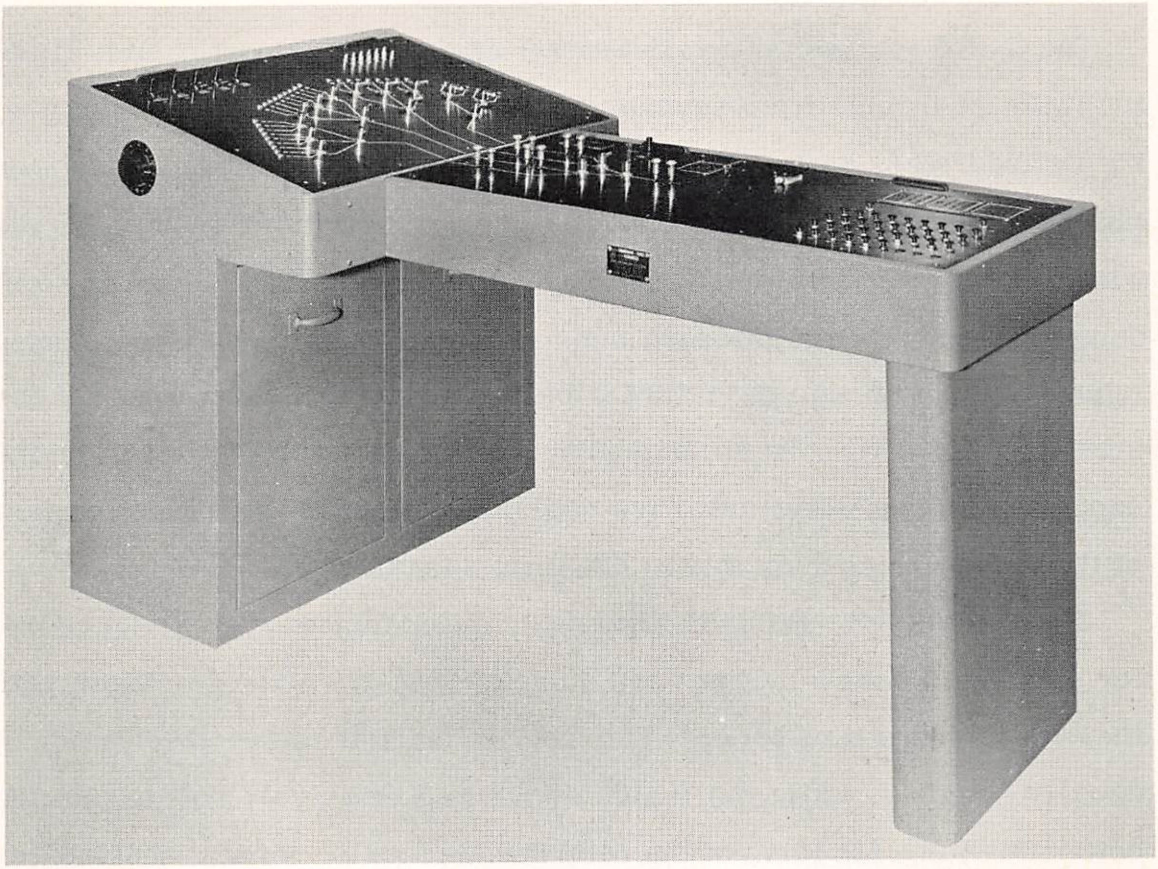

Figure 102. Combination pushbutton and retarder control machine.

such as:

1. Greater economy than other forms of power.
2. Minimum delays to yard operations.
3. Ability to provide storage-battery stand-by capacity for 6 to 12 hours of operation after failure of normal source of power.
4. Maximum safety, since retarders are normally left in a closed position and will continue to provide retardation indefinitely when so set, even if all power fails.
5. Transmission losses in transferring energy from source to retarder are very low.
6. Cold weather does not affect transmission of electrical energy. Freezing is no problem.

OTHER FEATURES

The G-R-S retarder is an all-weather device, and is particularly fitted to minimize trouble from severe winter weather. Since, in normal use, the retarders are kept closed, the shoes are spaced a distance narrower than the thickness of the car wheels. Any movement of the shoes by the wheels is therefore outward, preventing the packing of snow or sleet between the shoes and the rail, and assuring full shoe pressure. Snow cannot easily drift into the retarder because of the shielding effect of the structure supporting the shoes, and accumulations of ice and snow on the exposed portions of the unit have negligible effect on operation because of the large forces available to break up such deposits.

The G-R-S retarder is designed for maximum wear resistance and for easy maintenance. Shoes are made of heat-treated alloy steel, with the outside shoes hard because they contact the side of the wheel which is usually rougher, while the inside shoes are relatively soft to provide better friction. All parts of the retarder, except the levers, shoe beams and springs, which are actuated by the car wheels, remain stationary while a car is being retarded. Therefore, only the few bearings associated with these components are subject to frequent motion. The other bearings are used only when changes are made in the degree of retardation, and hence are moved relatively infrequently, with correspondingly little wear.

The G-R-S retarder is simple in construction, which makes for easy installation and maintenance. Any part can be reached in a short time, and parts are interchangeable between retarders, so that spare parts requirements are minimized. Accurate surface alignment is not needed, and considerable misalignment of track, caused by shrinkage of fill, or heaving from frost, can be tolerated without sacrificing operation and without breaking parts. Routine maintenance consists only of adjusting for shoe wear (accomplished by a single adjustment), replacing worn shoes, occasional tightening of bolts, and lubrication. Even a major overhaul consists of no more than replacing worn pins and bushings, and building up other worn parts by welding.

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SUBWAY SIGNALING

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INTRODUCTION

Subway signaling differs from signaling on surface railways principally in the matter of closer roadway clearances. To fit into the small space available in tubes and tunnels, such apparatus as signals, switch machines, and instrument cases, are designed with different shapes from those commonly used on surface roads.

AUTOMATIC SIGNALS

In subway work, signals are of the color-light type, with red, yellow, or green aspects. The automatic block signal layout comprises one 3-aspect signal with its associated automatic stop and a wayside case with the control relays and power supply.

The three aspects of an automatic signal and their meanings or "indications" are shown in Figure 104. Below the three color lenses is an il-

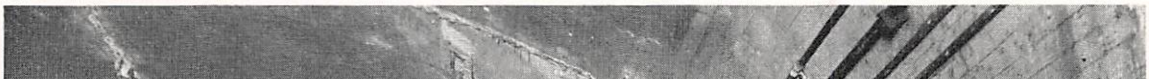


Figure 103. Wall-mounted subway signal and associated train stop between the rails.

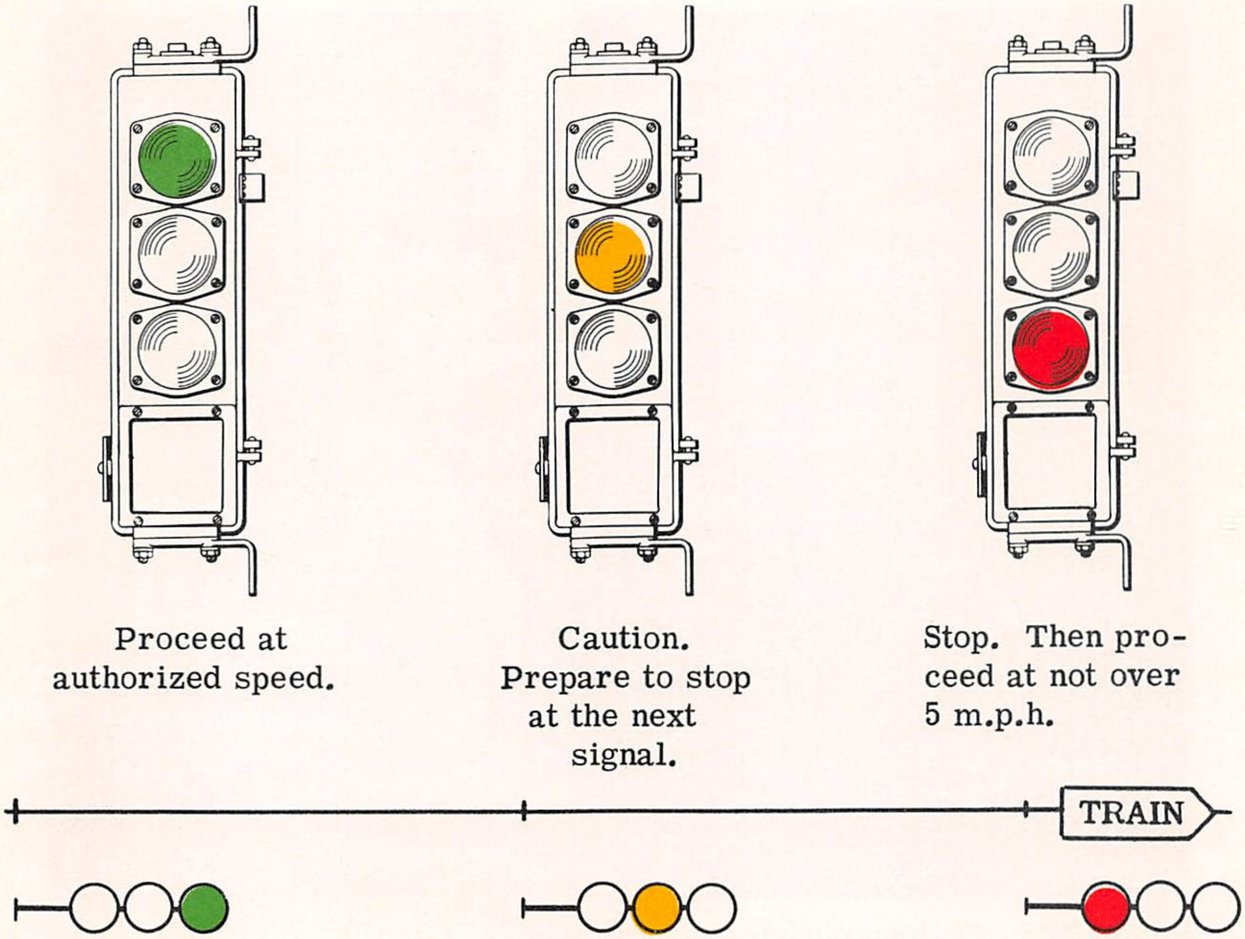

Proceed at authorized speed.
Caution. Prepare to stop at the next signal.
Stop. Then proceed at not over 5 m.p.h.
TRAIN

Figure 104. Automatic signals, their aspects and indications.

luminated number plate of milk-white glass. Two 10-volt, 5-watt lamps are connected in multiple for each aspect.

Signals are mounted on the columns, concrete wall, or on a pedestal, depending on the type of tube construction. Figure 103 illustrates a wall-mounted signal and its associated train stop placed between the rails.

Signals suspended from the ceiling over station platforms are arranged in a horizontal position with the red light on the track side, followed by yellow, then green. A ceiling-mounted signal is shown in Figure 105.

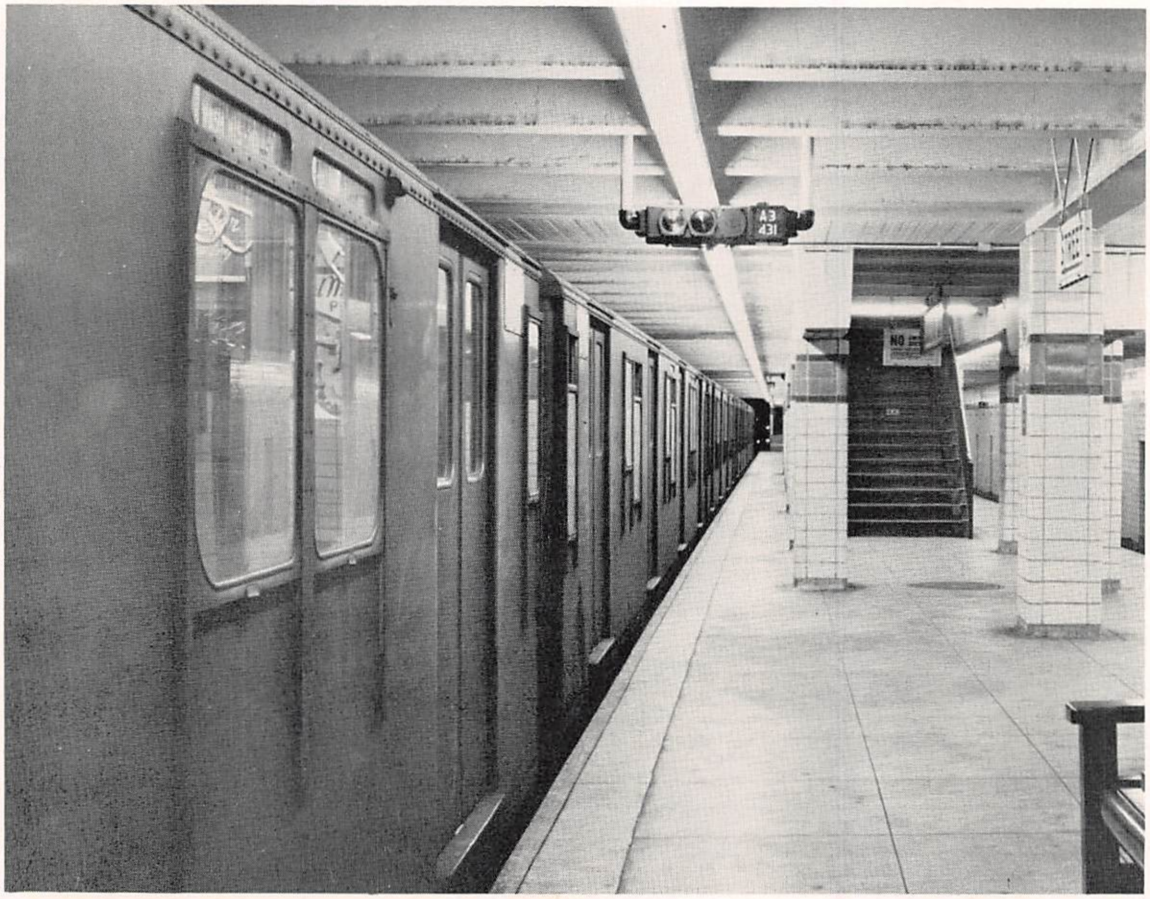


Figure 105. Ceiling-mounted subway signal.

INTERLOCKING SIGNALS

An interlocking home signal layout usually comprises a signal made up of two 3-aspect units with an additional single aspect (yellow), an automatic train stop, and a release pushbutton located from 3 to 5 feet to the rear of the signal and within reach of the motorman. Such a layout is shown in Figure 106.

The top unit of the interlocking home signal, Figures 107 and 108, gives the same indications as the automatic signal in Figure 104. The bottom unit indicates whether the indications of the top unit are for a straight or for a diverging route. The single lens unit at the bottom is a "call-on" unit, whose purpose is described later.

If a train is stopped by a red automatic signal, it can proceed at not over 5 miles per hour by the red signal. If a train is stopped at a home signal, it must stay until some proceed indication is received. If an emergency move is to be made, the train receives a yellow indication from the extra light unit (call-on) on the home signal, and the operator must push a button located on a post at the side of the track to clear the automatic stop, and then proceed at slow speed prepared to stop at once until he comes to a less restrictive signal.

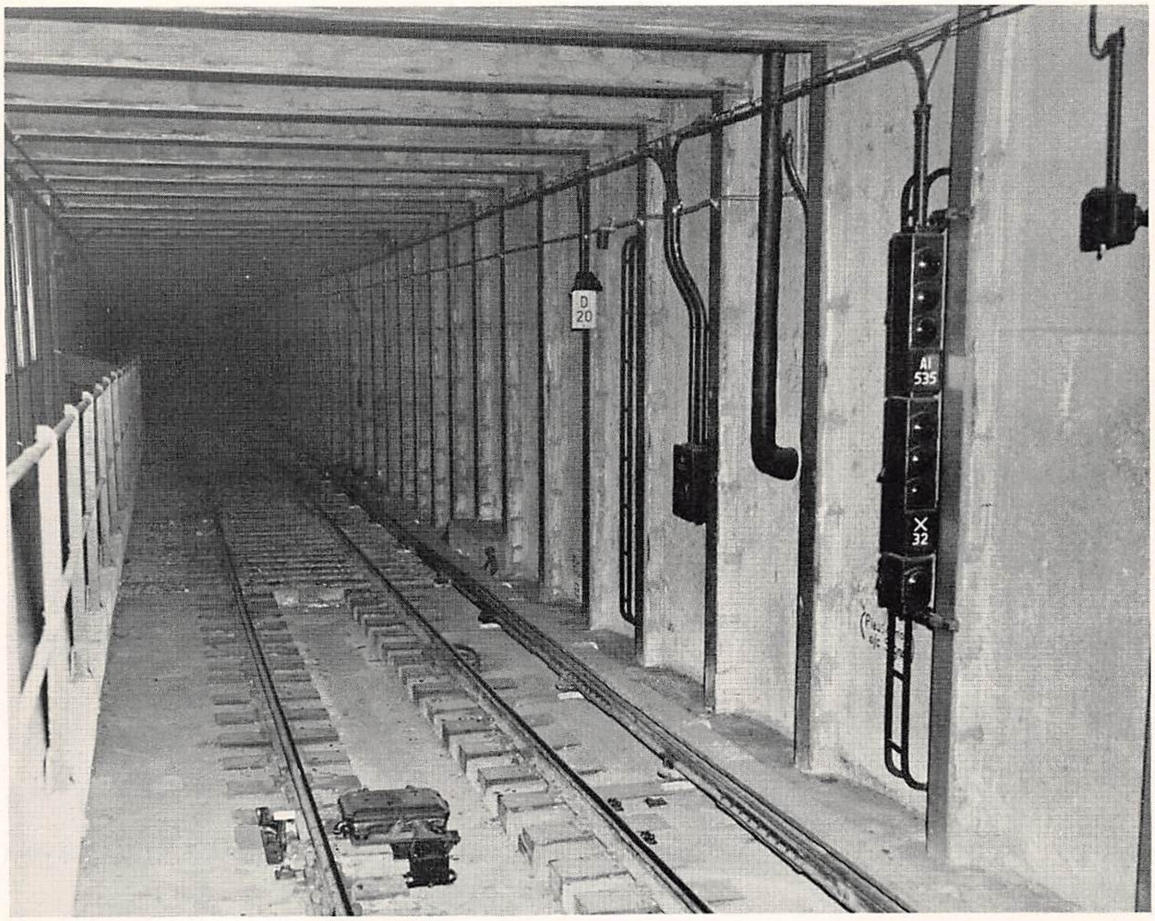
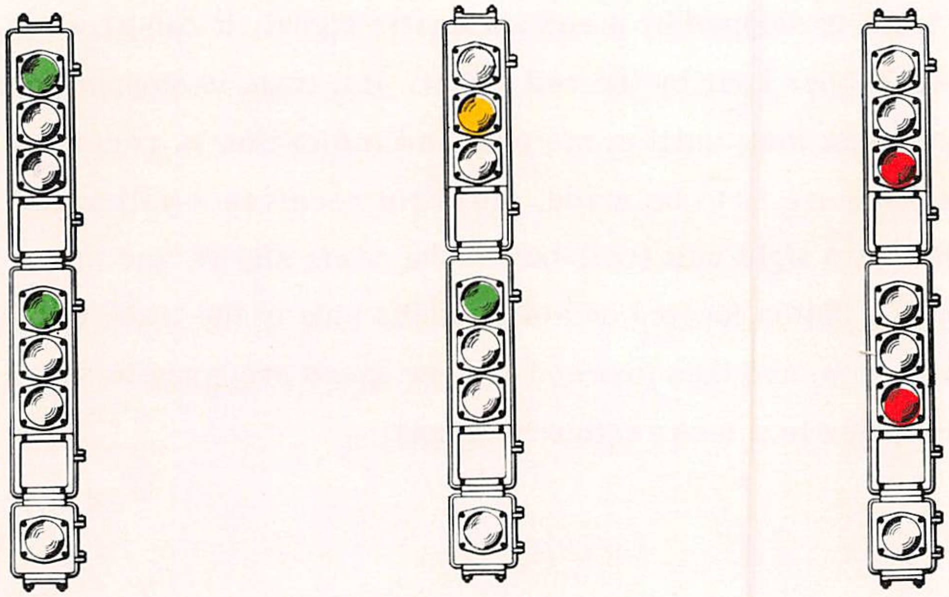


Figure 106. Subway interlocking signal layout with pushbutton release and automatic train stop.

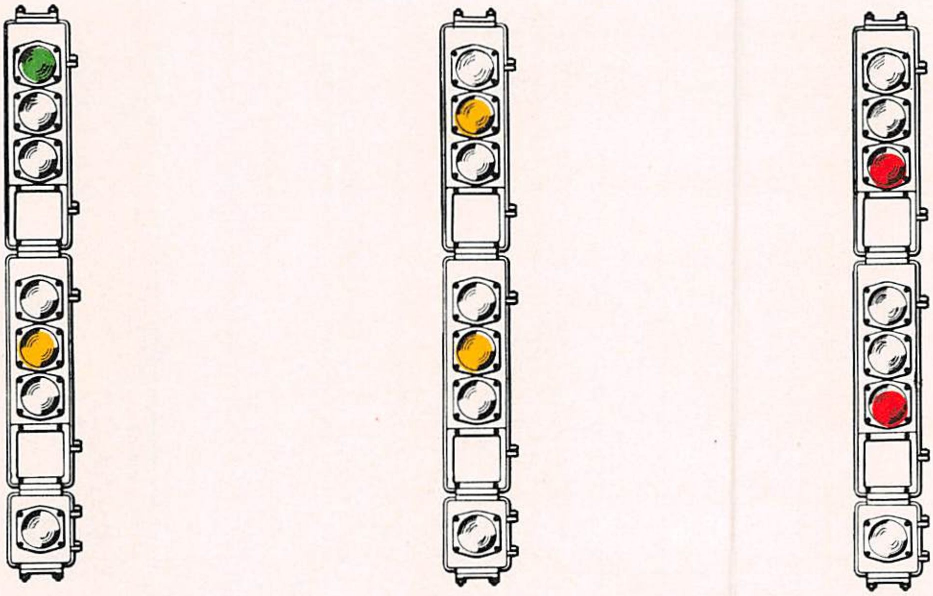


Clear. Proceed at authorized speed.

Caution. Prepare to stop at next signal.

Stop and stay.

Figure 107. Home signal aspects and indications for a straight route.

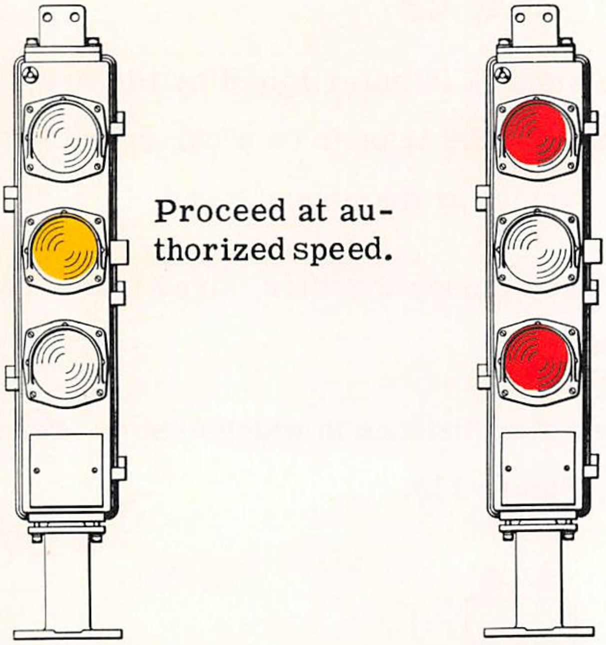


Clear. Proceed at authorized speed.

Caution. Prepare to stop at next signal.

Stop and stay.

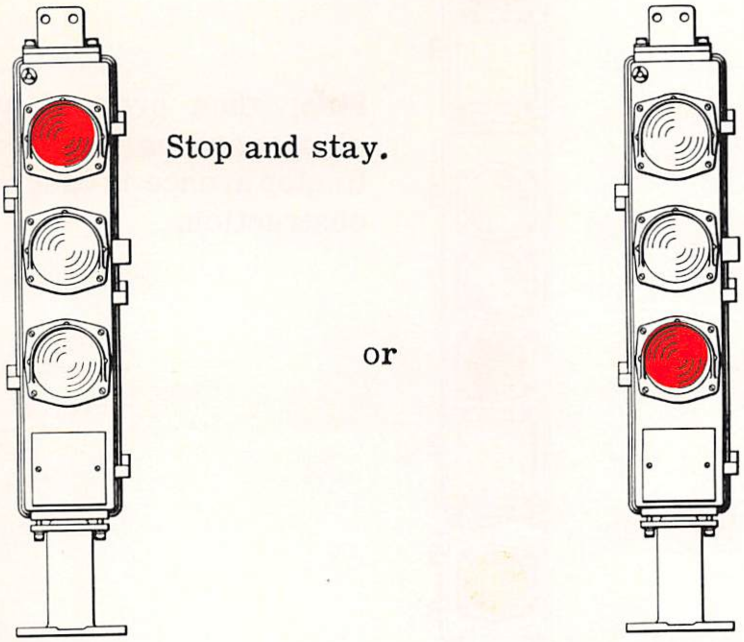
Figure 108. Home signal aspects and indications for a diverging route.



Proceed at authorized speed.

Stop and stay. Two reds are used to guard against a lamp's burning out.

Figure 109. Dwarf signal aspects and indications.



Stop and stay.

or

Stop and stay.

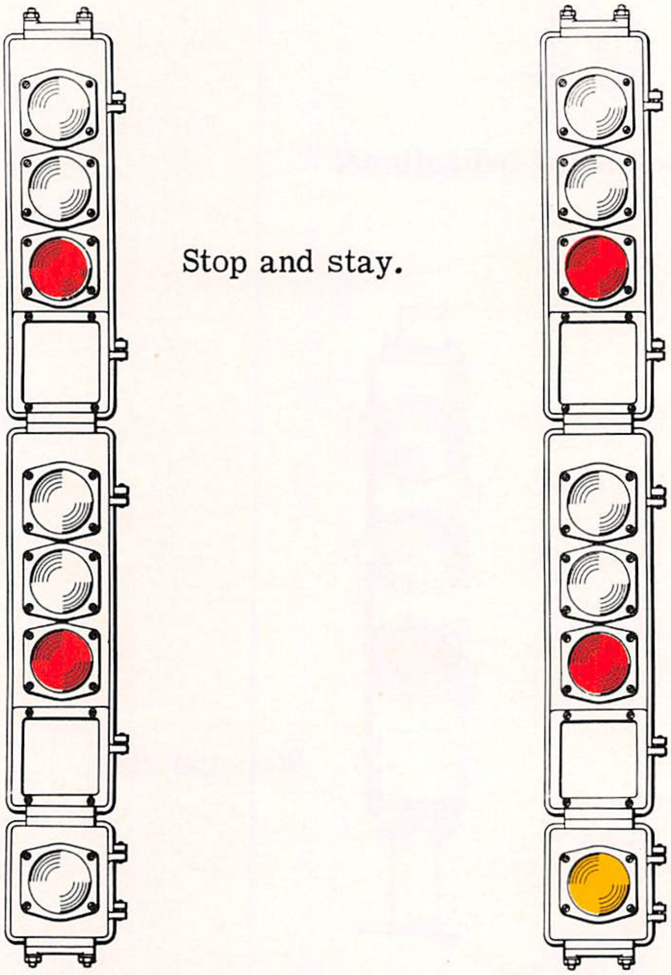
Figure 110. Dwarf signal aspect with one red lamp burned out.

SIGNAL SPACING

The spacing of the automatic signals is determined by the braking distance required to stop a train when the tripper on a car contacts an automatic stop arm with the car running at maximum speed.

On upgrade, signals can be spaced closer together, since trains can stop in a shorter distance, Figure 112.

On downgrade, trains require greater distance in which to stop. Hence signals are spaced further apart, Figure 113.



Stop and stay.

Stop, then proceed at slow speed; be prepared to stop at once in case of obstruction.

Figure 111. The use of the "call-on" yellow unit on the home signal.

Similarly, where trains are traveling slower, as when approaching stations, signals can be spaced closer together.

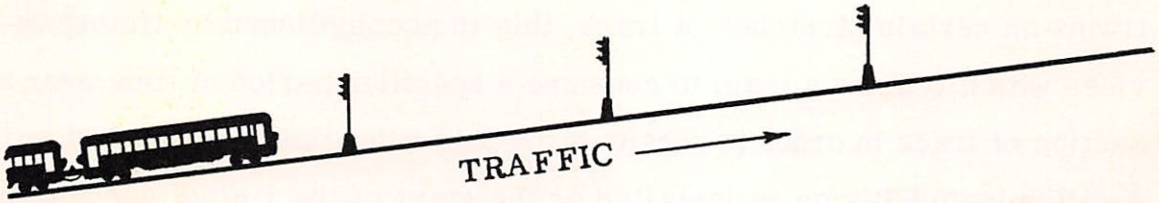


Figure 112. Upgrade signals.

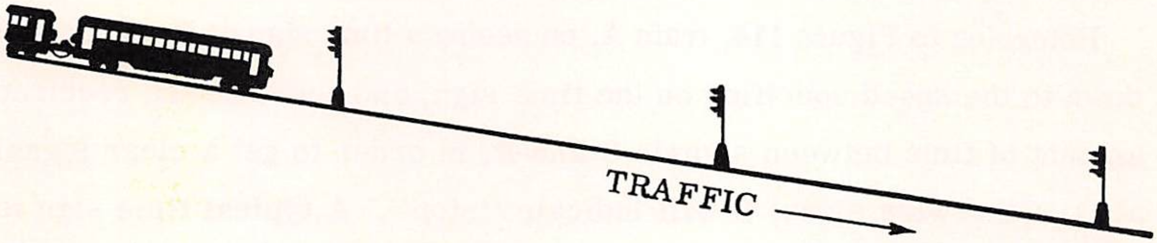


Figure 113. Downgrade signals.

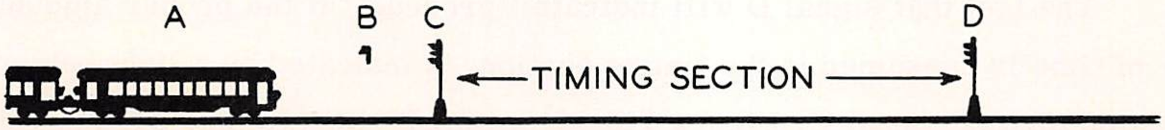

A
B
C
D
TIMING SECTION

Figure 114. Timed signals.

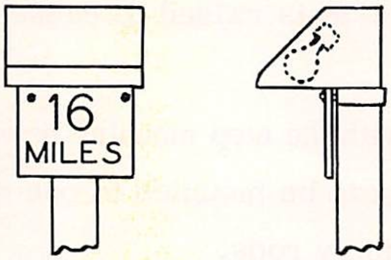


Figure 115. Time sign at B.

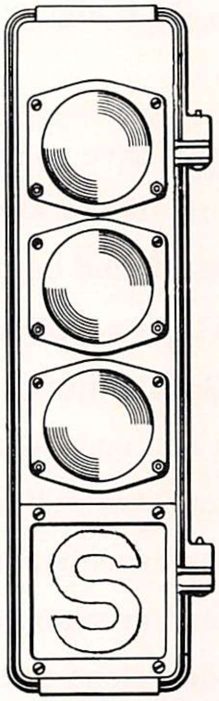


Figure 116. Signal at C.

TIMED SIGNALS

If track conditions are such that it is desirable to limit the speed of trains on certain stretches of track, this is accomplished by timing devices which require a train to consume a specified period of time over a section of track in order to receive a proceed indication at the next signal. An illuminated T sign is installed at the start of the timing section to warn an approaching train that speed control is effective.

Referring to Figure 114, train A, on seeing a time sign at B, must slow down to the speed specified on the time sign, and consume the required amount of time between signals C and D, in order to get a clear signal at D. Otherwise signal D will indicate ''stop''. A typical time sign is shown in Figure 115.

The fact that signal D will indicate ''proceed'' if the proper amount of time is consumed in the timing section, is indicated by a light behind an S sign on signal C, Figure 116. If signal D cannot clear because of obstruction, the S sign will not be illuminated.

TRAIN STOPS

Train stops have an arm which is raised or lowered, depending on the signal aspect. If the signal is at stop, the arm is raised to cause the brakes to be applied on the train.

Figure 117 is a typical train stop layout, with the stop mounted between the rails. Where this is not feasible, stops can be mounted to one side of the track and connected to the tripper arm by rods.

Train stops are self-contained mechanisms operating on alternating current. The essential parts are the motor, gear train, hold-clear mechanism, circuit-breaker, checking contacts, and a main shaft to which the external connections are made for operating the tripper arm.

The motor drives the arm downward to the clear position against a heavy spring in compression. The hold-clear mechanism holds the arm in this position with very small energy consumption. All energy is cut off the motor in this position.

When the block is occupied or power fails, the hold-clear is deenergized, and the arm returns to the stop position.

Signal controls are checked through the checking contacts.

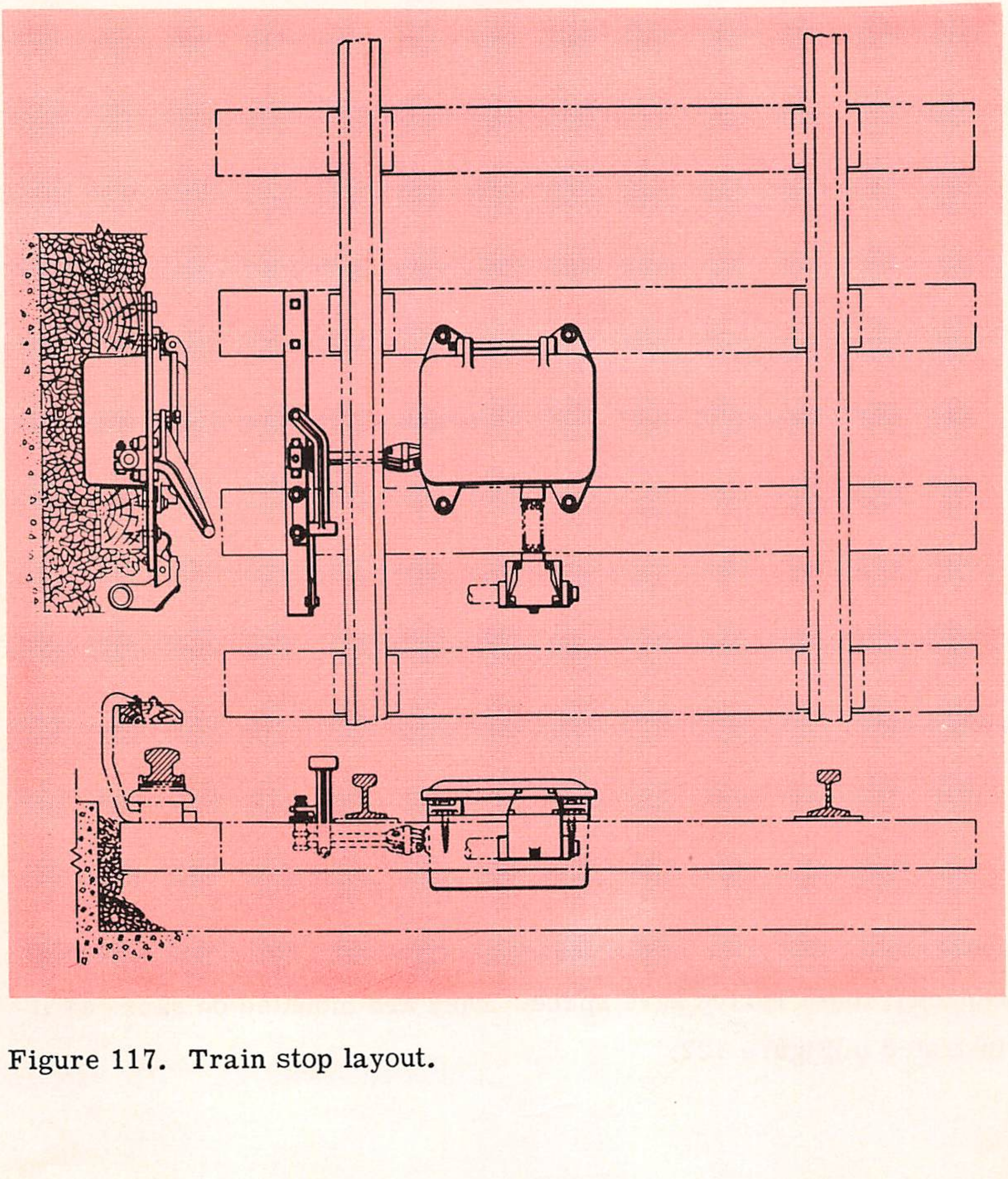


Figure 117. Train stop layout.

SWITCH LAYOUTS

The switch operating machines are the Model 5, operating on 110-volt direct current from storage battery charged by rectifiers. These machines consist of a motor, gear train, throw and lock rods, and a pole-changer mechanism for changing the direction of movement of the motor.

Point position is detected by a switch circuit controller.

A typical switch layout is shown in Figure 118. The Model 5 switch machine is illustrated in Figure 119.

WAYSIDE CASES

Relays and power equipment along the tracks are housed in compact cases, such as those shown in Figure 120. As can be seen, these cases are single or double, depending upon the space required. Pedestals of different heights are provided under the cases to bring them up to a convenient height for the maintainer.

To facilitate maintenance, Type B plug-coupled relays are used. To change out one of these relays takes a few seconds. The maintainer does not disturb the wiring, Figure 121.

CONTROL MACHINES

At interlockings, several different forms of control have been provided, the latest of these being the NX (eNtrance - eXit) system of electric interlocking. The reader is referred to the section on interlocking for details on the various systems available.

RELAY ROOMS

Since space is at a premium underground, the Type B plug-in relay has met with favor. Small, compact, and with a relatively large contact capacity, these relays save space. They are mounted on racks as illustrated in Figure 122.

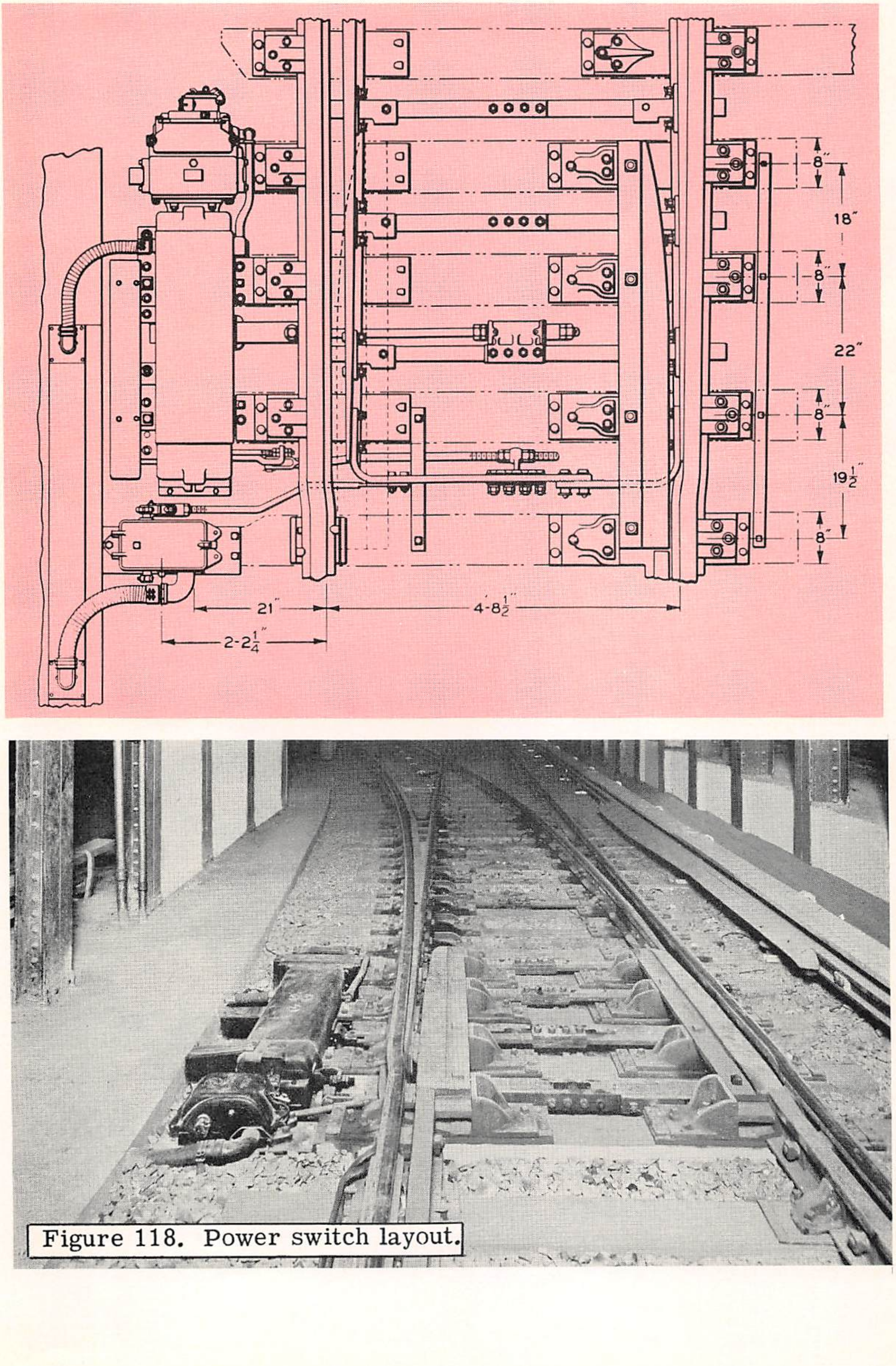

8"
18"
8"
22"
8"
19½"
8"
21"
4'-8½"
2-2¼"

Figure 118. Power switch layout.

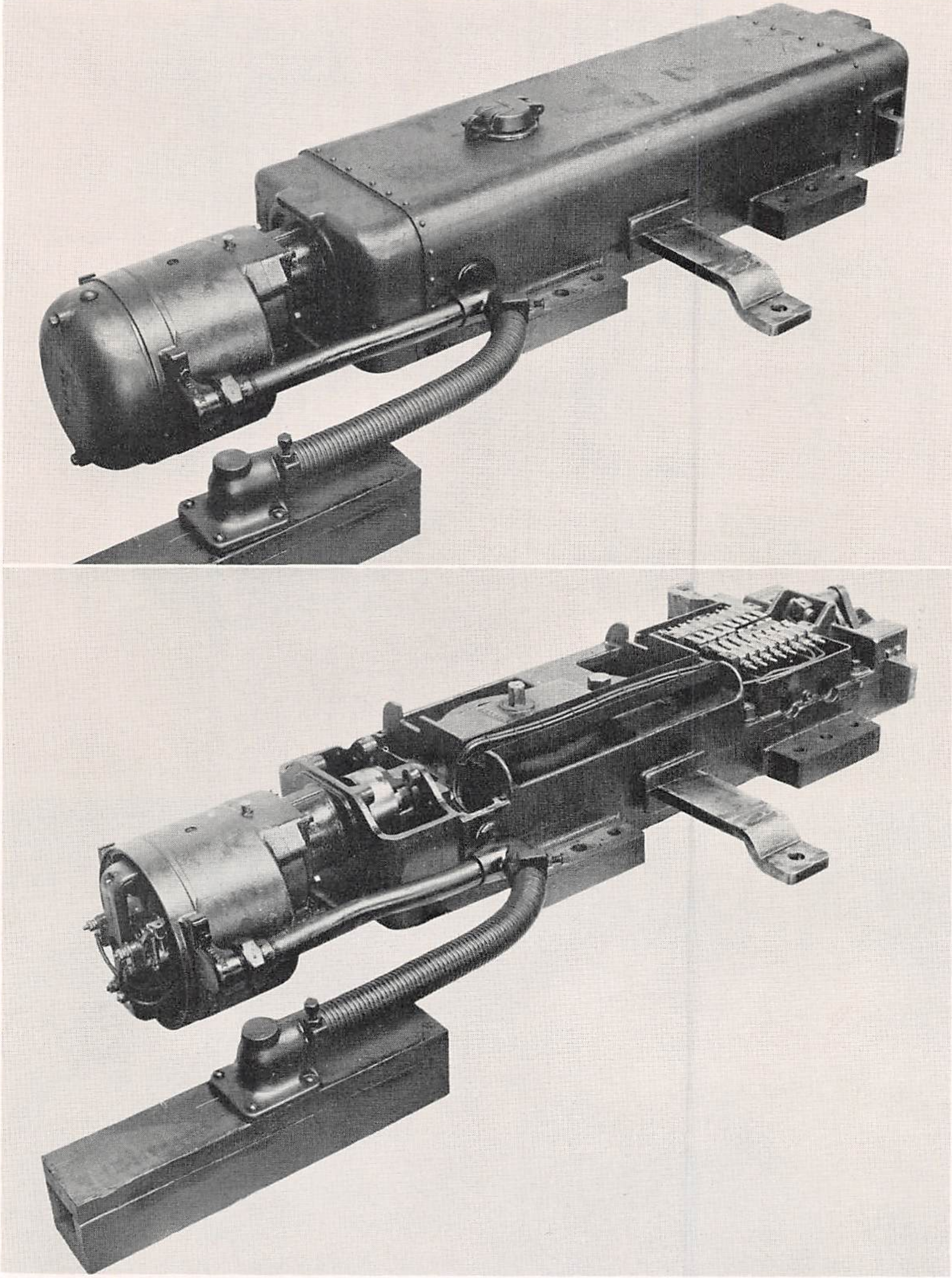


Figure 119. Model 5 switch machine. Bottom illustration shows machine with cover removed.

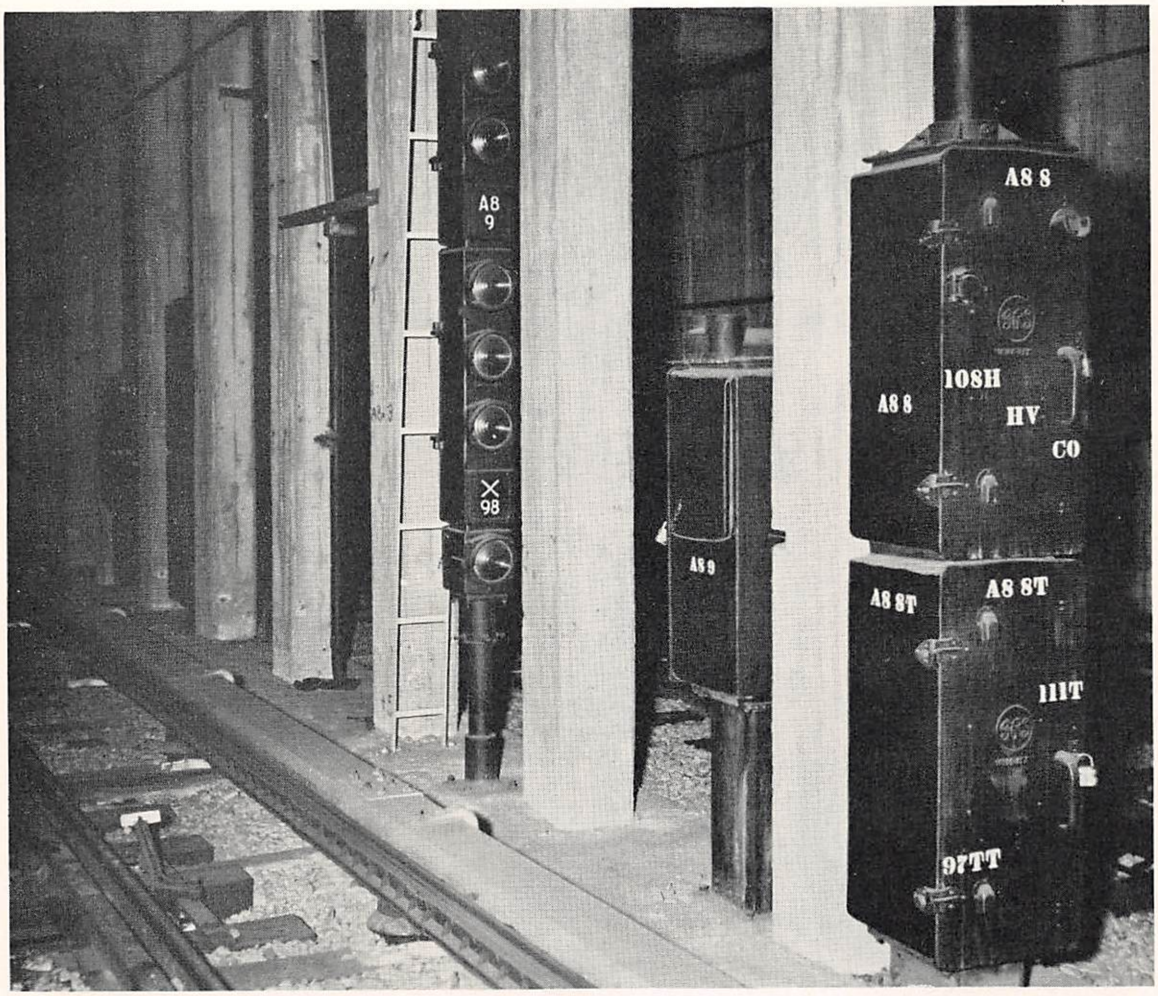


Figure 120. Typical wayside cases showing double- and single-case arrangement.

POWER EQUIPMENT

On racks similar to those supporting the B relays are copper-oxide rectifiers for charging switch operating batteries and low voltage batteries for the control circuits. Switchgear, meters, fuses, etc. are mounted conveniently on the same racks, as can be seen in Figure 123.

G-R-S SUBWAY SIGNALING EXPERIENCE

Since the early years of the present century, the General Railway Signal Company has made and furnished to the leading subway systems

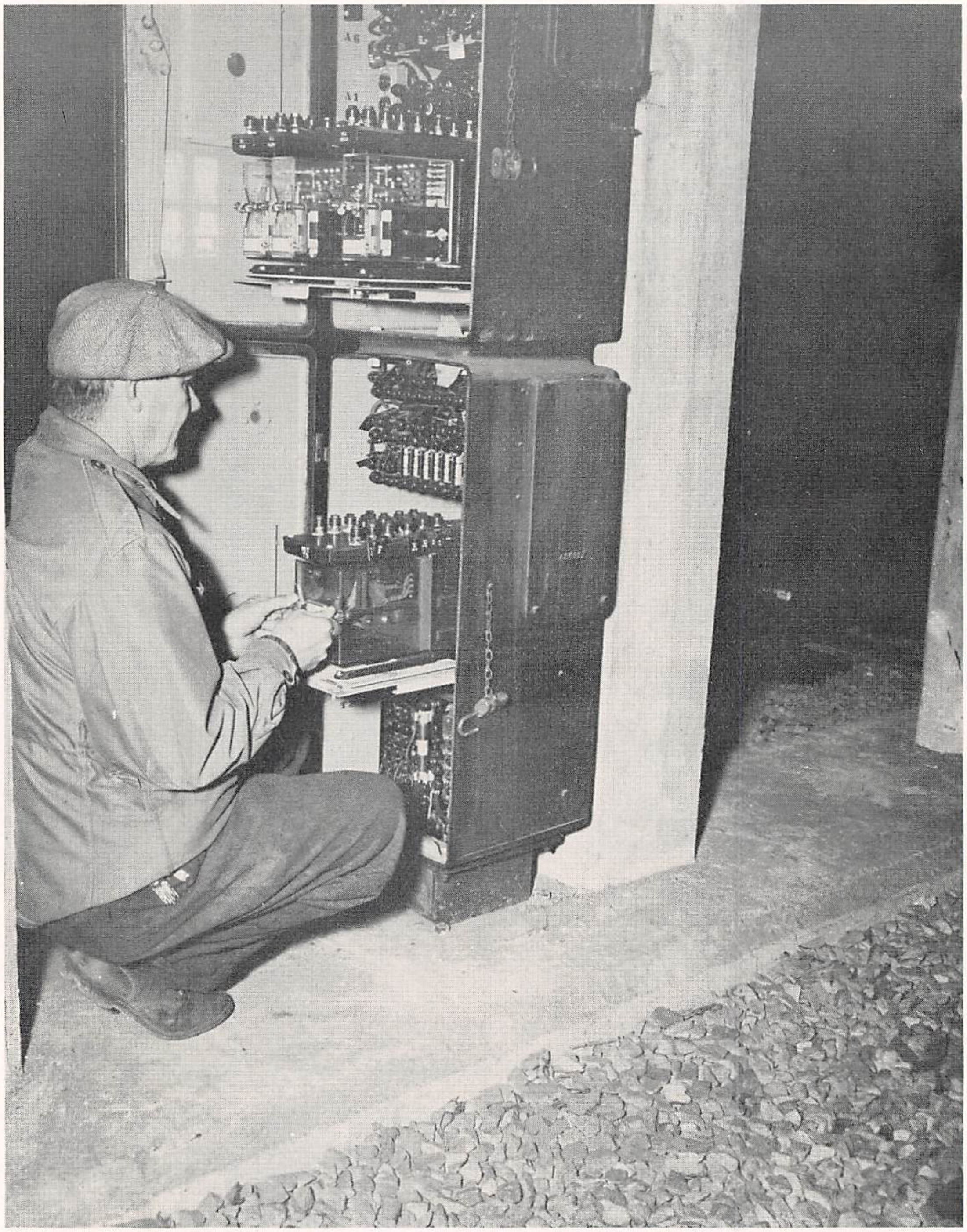


Figure 121. Type B plug-coupled relays can be removed or replaced quickly, without disturbing wiring.

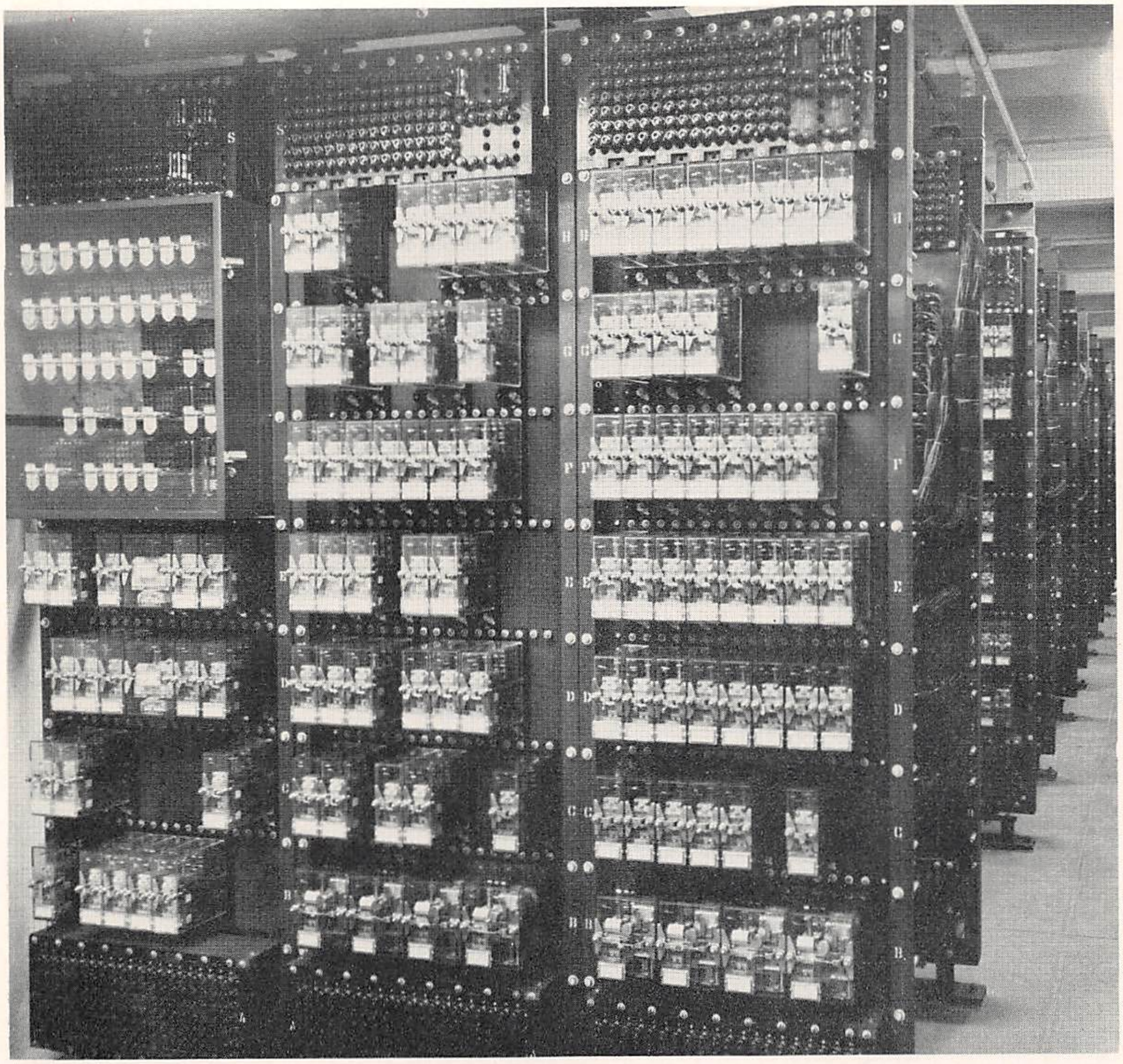


Figure 122. Type B relay racks.

of the world a complete line of subway apparatus. The design of this apparatus takes into account years of experience with moisture problems, electrolysis, interwire capacitance, grounding, vibration, and the many other problems that beset subway practice. Track circuits are tested on an artificial track to simulate actual conditions of operation so that the proper apparatus can be furnished. Circuits have been developed to provide the highest degree of safety to trains operating on close headway. A cab signal and speed control system has been installed and has achieved an outstanding operating record. See sections on cab signals and on continuous inductive train control for more data on these subjects.

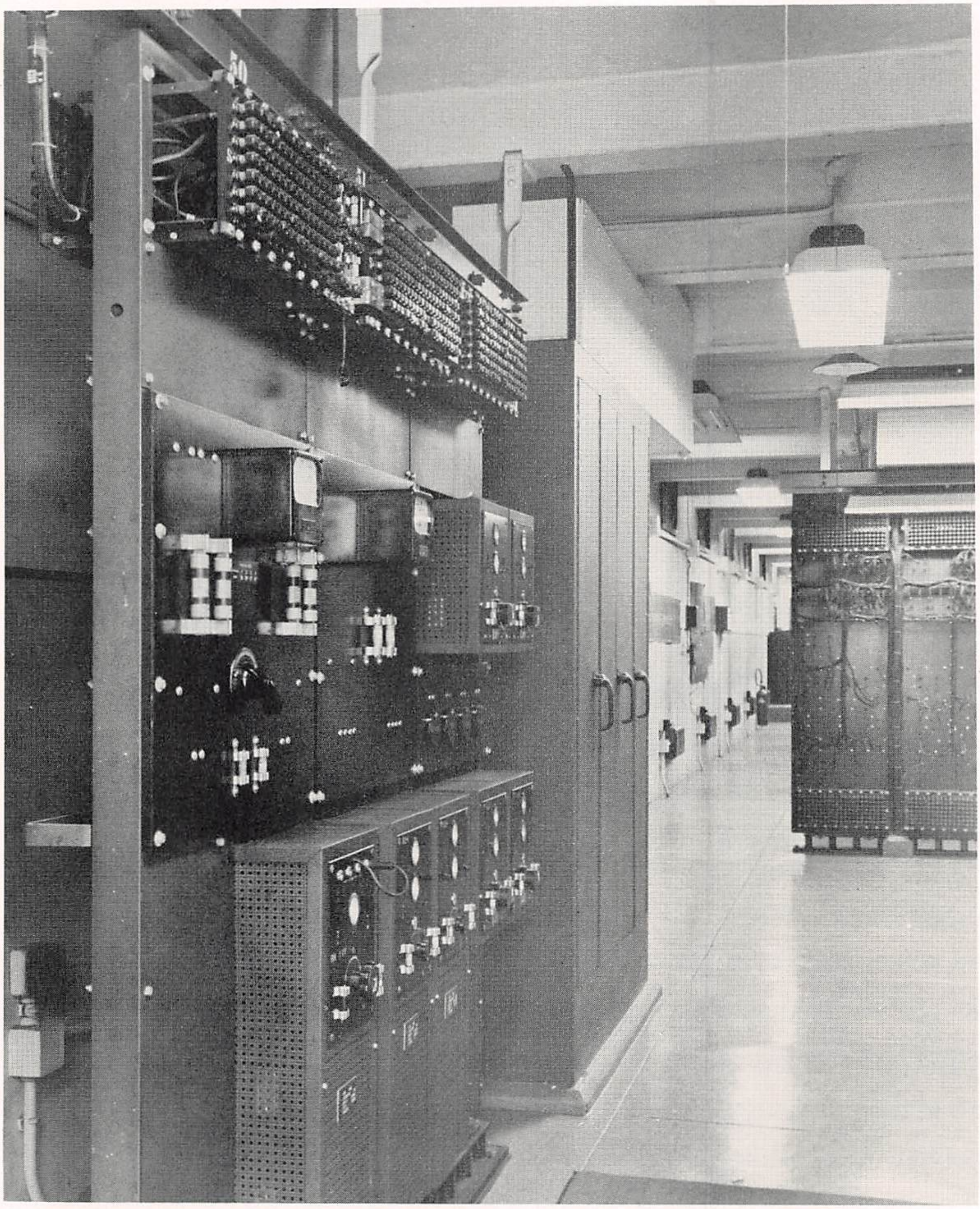
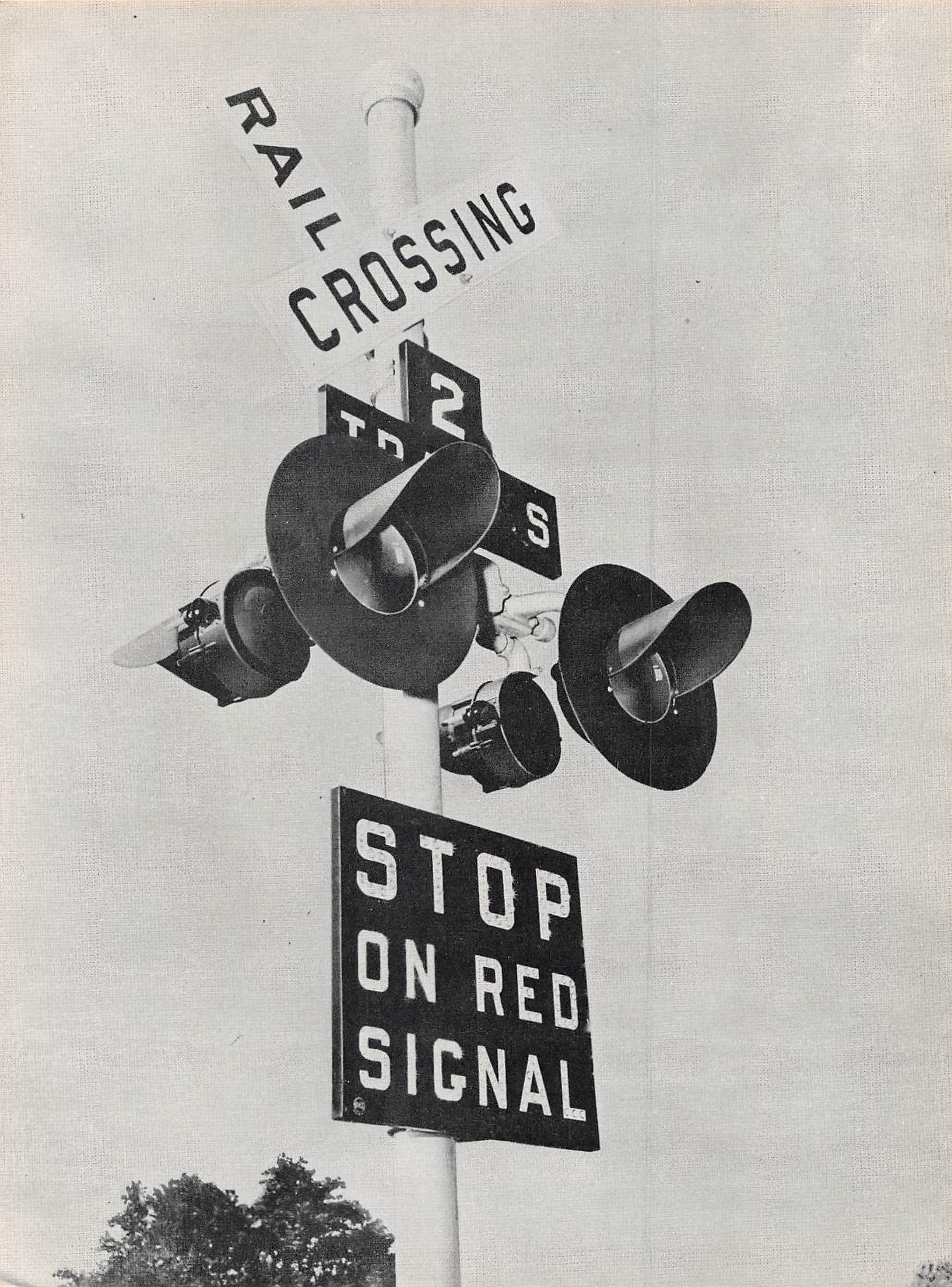


Figure 123. Rectifiers, switches, meters, fuses, etc., are mounted on the same type racks used for the Type B relays.


RAIL
CROSSING
2
S
STOP
ON RED
SIGNAL

HIGHWAY CROSSING PROTECTION

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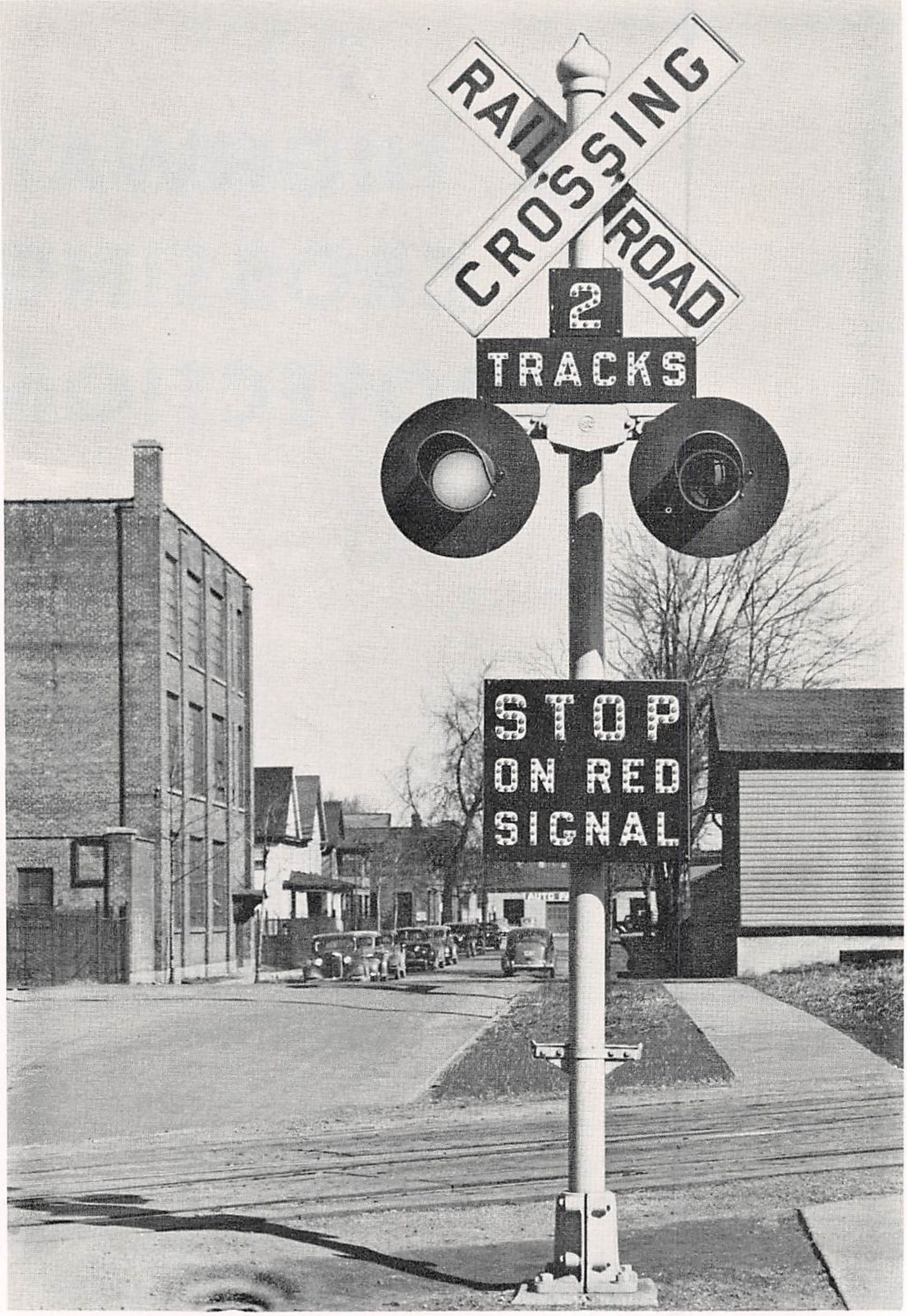

RAILROAD
CROSSING
2
TRACKS
STOP
ON RED
SIGNAL

Figure 124. Flashing-light crossing signals provide continuous, automatic protection.

INTRODUCTION

Efficient highway crossing protection may be provided by flashing-light signals, either alone or with electrically operated gate arms. Either arrangement may be controlled automatically by track circuits or manually by an attendant. Manual operation may be from a point remote from the crossing if desired.

FLASHING-LIGHT SIGNALS

Figure 124 shows a typical G-R-S flashing-light signal. The highly efficient light units project brilliantly colored warning beams for a minimum of 1500 feet in bright sunlight - nearly eight times the stopping distance of an automobile traveling 50 miles an hour. Entirely visual, the warning is not affected by street noises or by sounds within the automobile. The powerful, flashing beam is distinctly different from that of an ordinary traffic signal.

Figure 125, shows a complete signal equipped with relay case, four light units, cast iron crossbuck sign and reflector-button track and stop signs. This is only one of many possible arrangements. Mast may be any of various heights with plain or junction-box base instead of relay case. Crossbuck may have reflector-button lettering. Light units may be mounted on cantilever arms extending from 6 to 12 feet from mast.

If you want lettering on signs to be other than English, we can send you blank signs and separate reflector buttons so you can drill the signs, enamel the lettering, and install the reflector buttons as you require. Cast iron crossbuck signs can be supplied blank so you can paint lettering on them as required.

Light units have adjustable mounting elbows so the light beam can be aimed where you want it. The red signal roundels are 8-3/8 inches in diameter and are available with various optical characteristics so you can spread the light beam over the desired area.

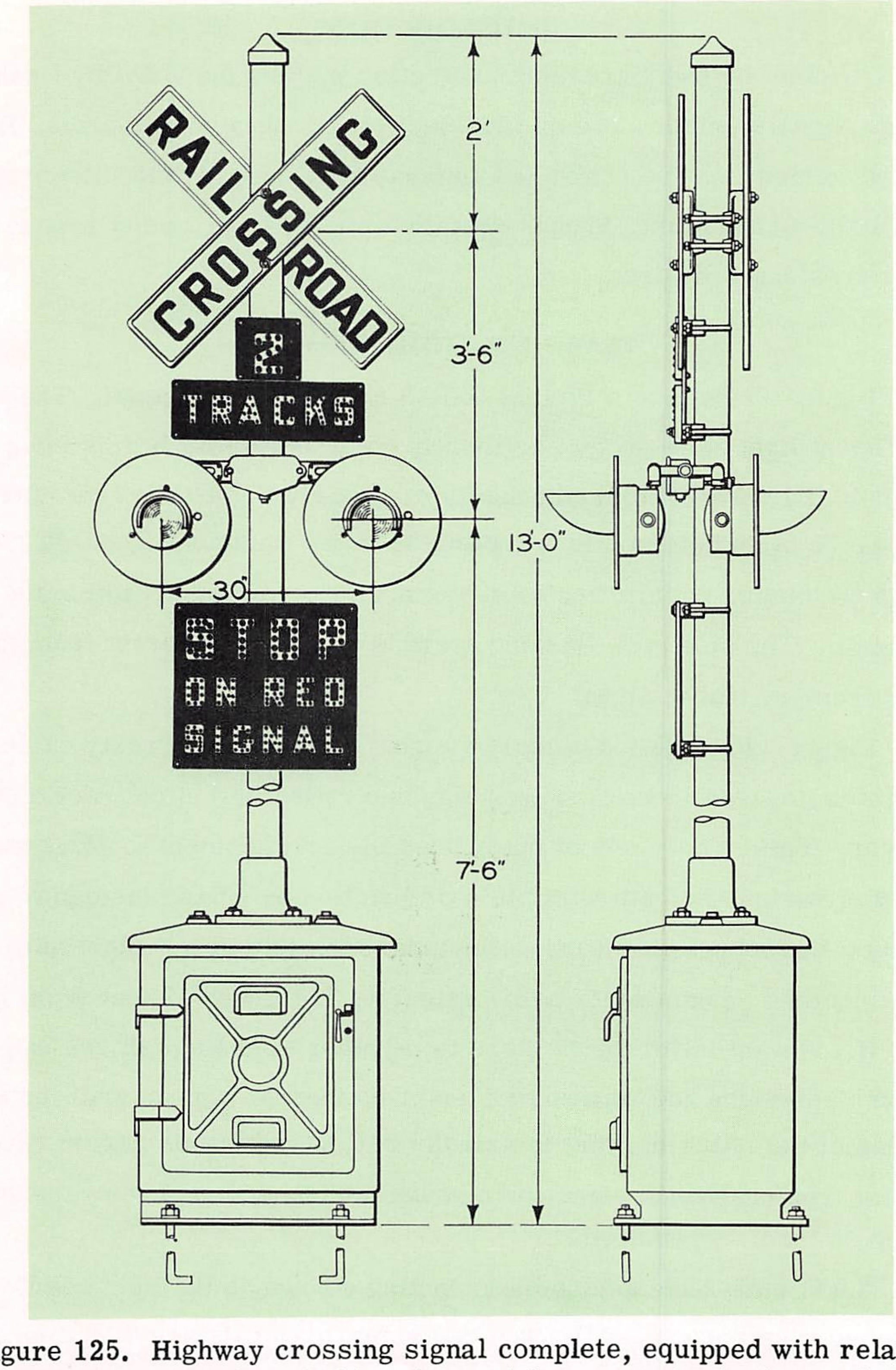

RAILROAD
CROSSING
2
TRACKS
STOP
ON RED
SIGNAL
2'
3'-6"
13'-0"
7'-6"
30"

Figure 125. Highway crossing signal complete, equipped with relay case, four light units, cast iron crossbuck sign, and reflector-button stop and track signs.

ELECTRIC GATES

Figure 126 shows a flashing-light signal with electrically operated gate arm. Figure 127 shows, in more detail, how the various units are arranged. Note that an extra pair of flashing lamps is provided on this installation to cover an additional street approaching the crossing at other than right angles. Figure 128 shows two views of the gate operating mechanism, a motor, gear train, and circuit controller.

Maximum length of gate arms is 40 feet. If desired, sidewalk arms may be added to protect pedestrian traffic. Sidewalk arms are shown, on right side of case, in Figure 128.

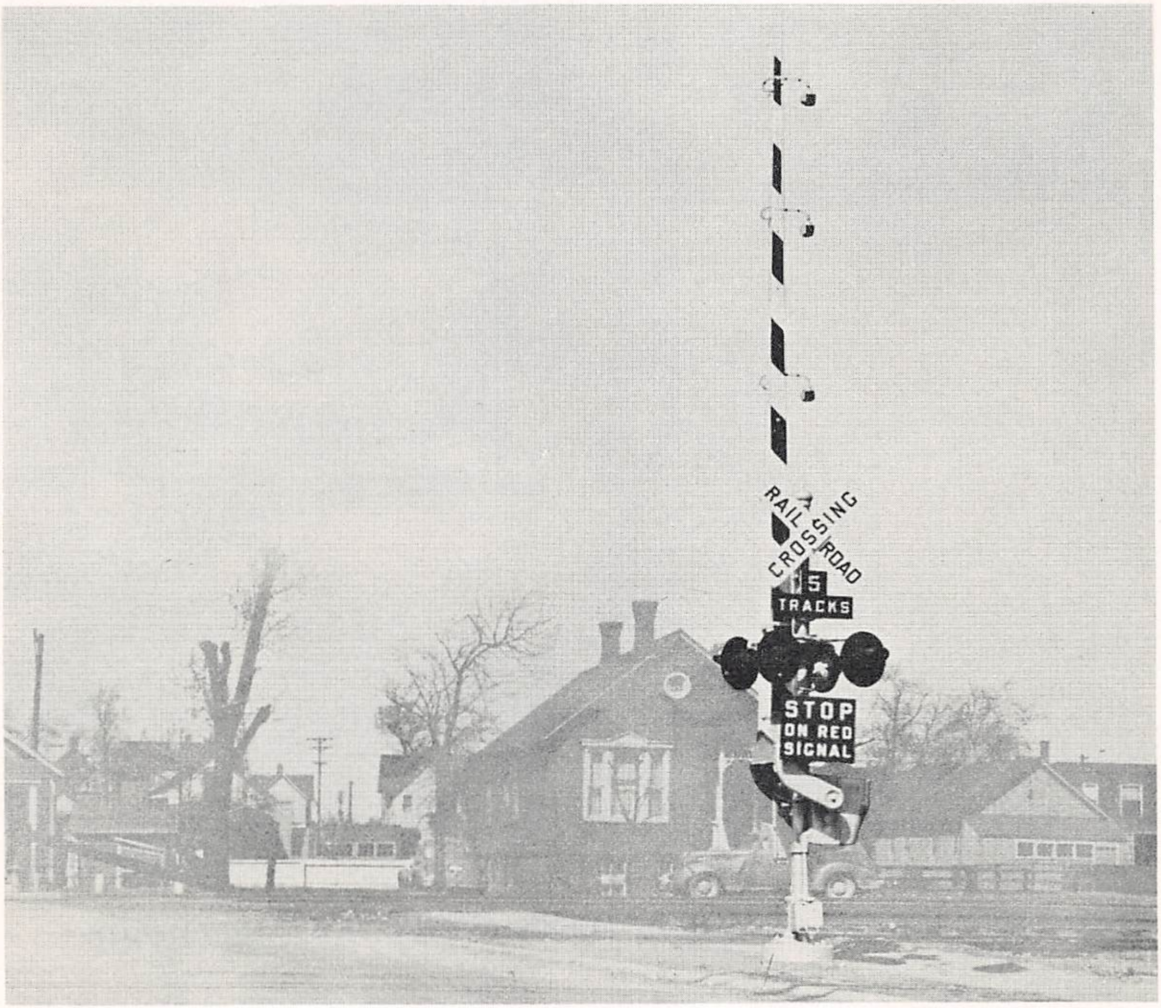


Figure 126. Flashing-light highway crossing signal with electric gate.

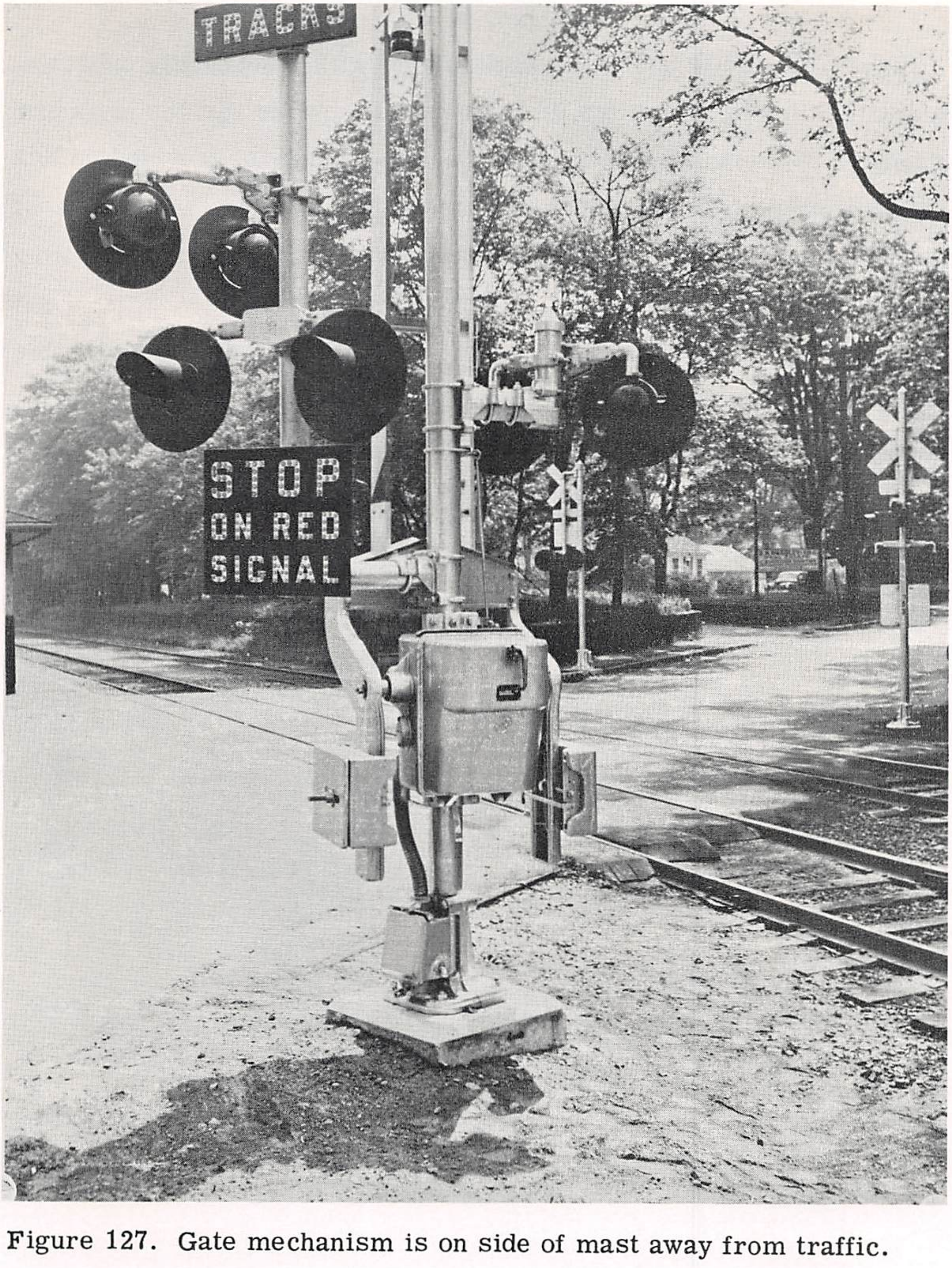

TRACKS
STOP
ON RED
SIGNAL

Figure 127. Gate mechanism is on side of mast away from traffic.

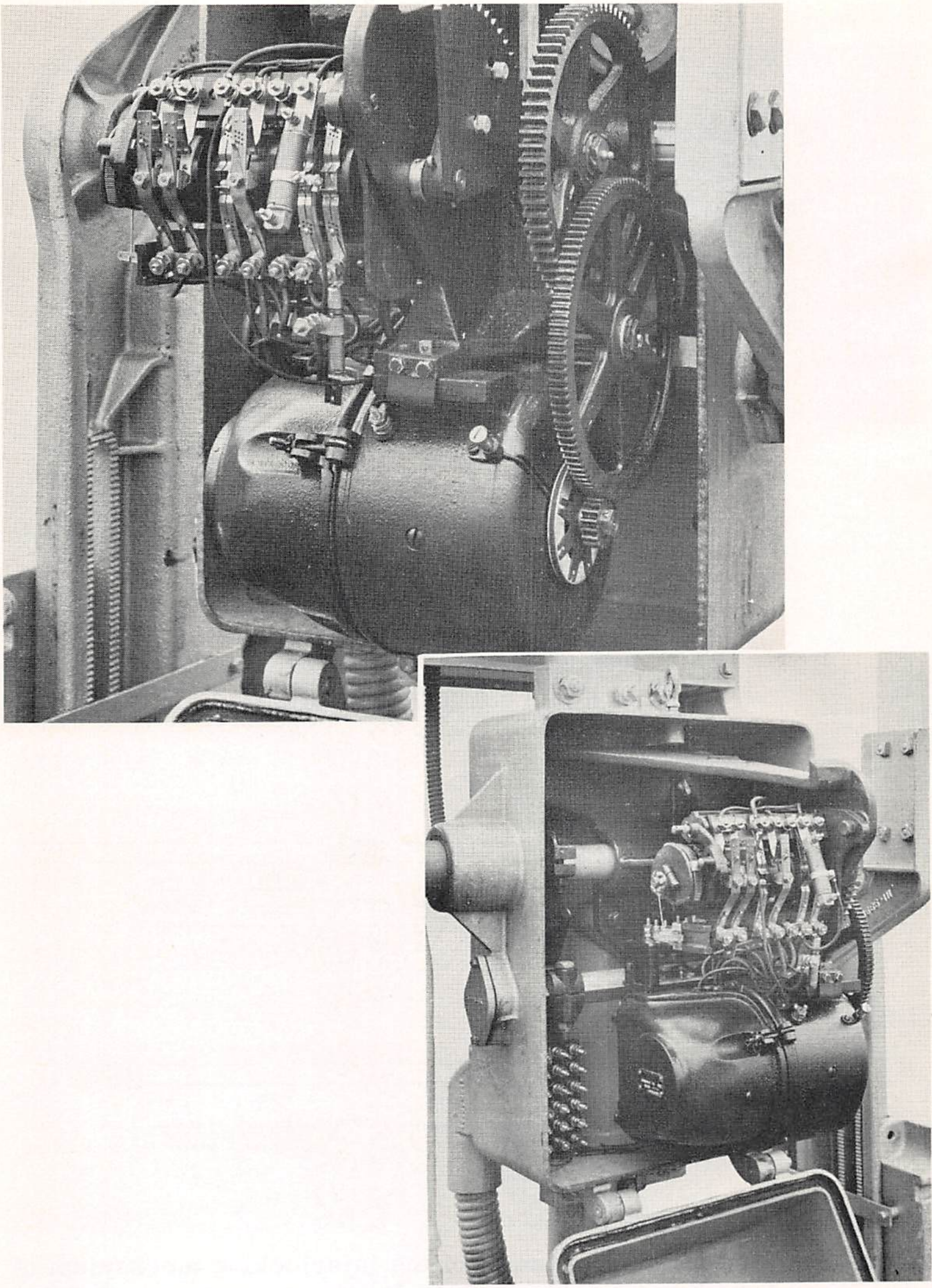


Figure 128. Gate mechanism motor, gear train, and circuit controller.

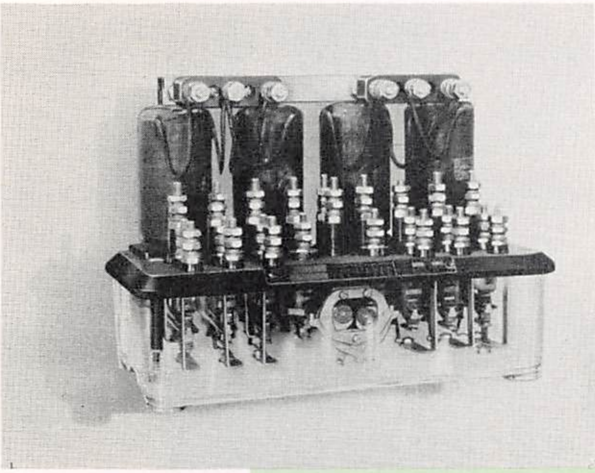


Figure 129. Type K interlocking relay.

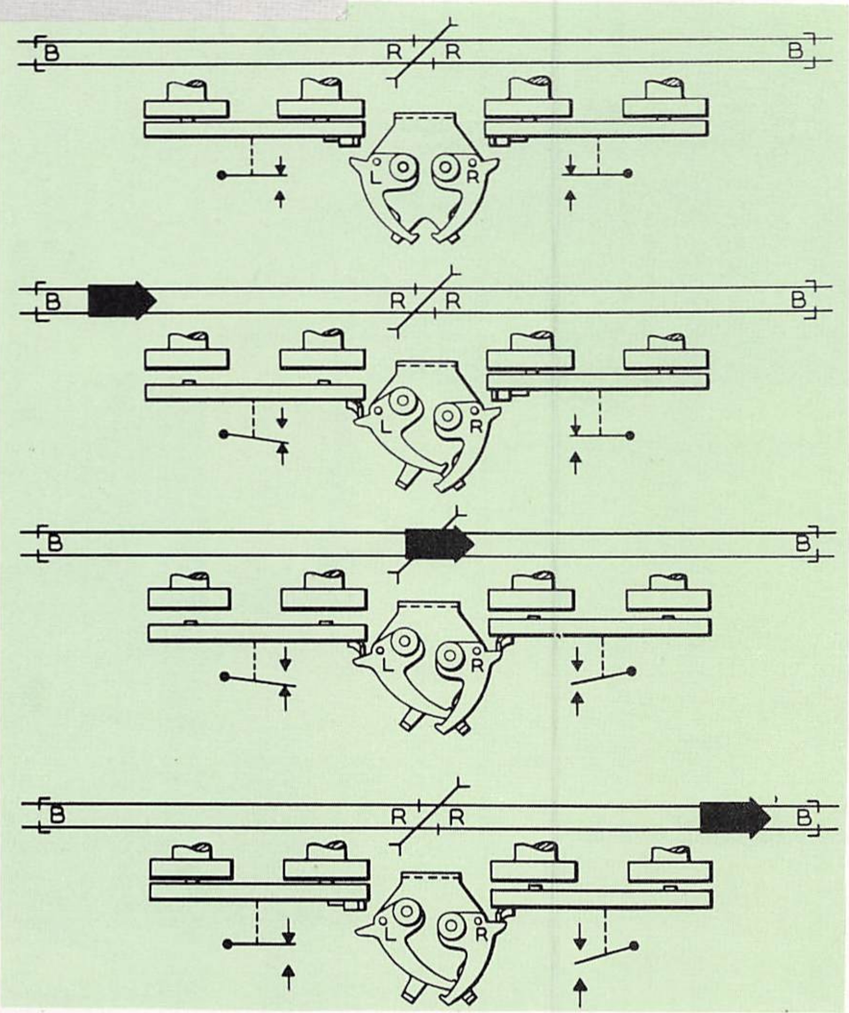


Figure 130. Sequence of operation of the interlocking mechanism of Type K interlocking relay. B indicates battery and R indicates relay on track diagram.

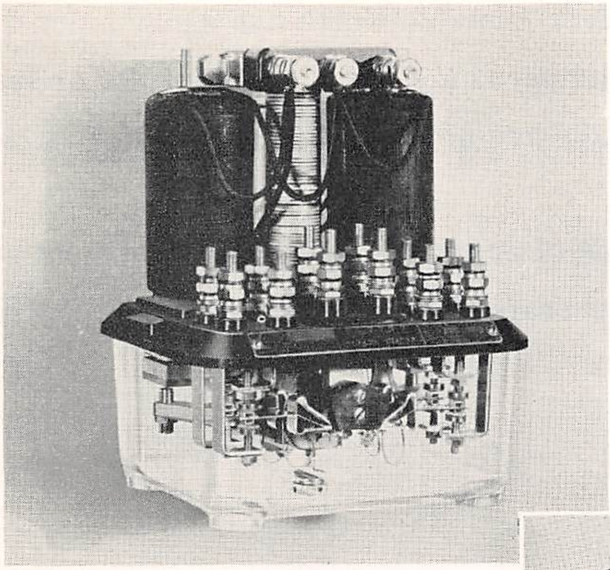


Figure 131. Type K flashing relay, tractive-armature type for wall or shelf mounting.

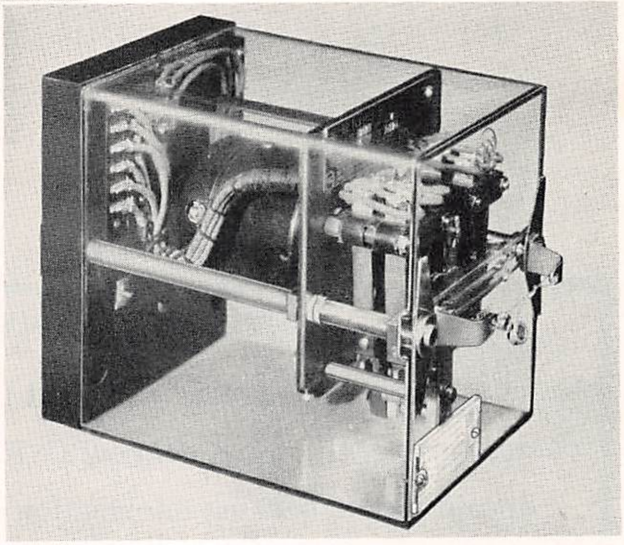


Figure 132. Type B flashing relay, motor-operated type for plug-in mounting.

INTERLOCKING AND FLASHING RELAYS

An interlocking relay, Figure 129, is used to control the signals where trains operate in both directions on single track. The same results can be secured by using four ordinary neutral relays. In such an arrangement, however, the relays are electrically instead of mechanically interlocked.

Two types of flashing relays are available, the tractive-armature type, Figure 131, and the motor-operated type, Figure 132.

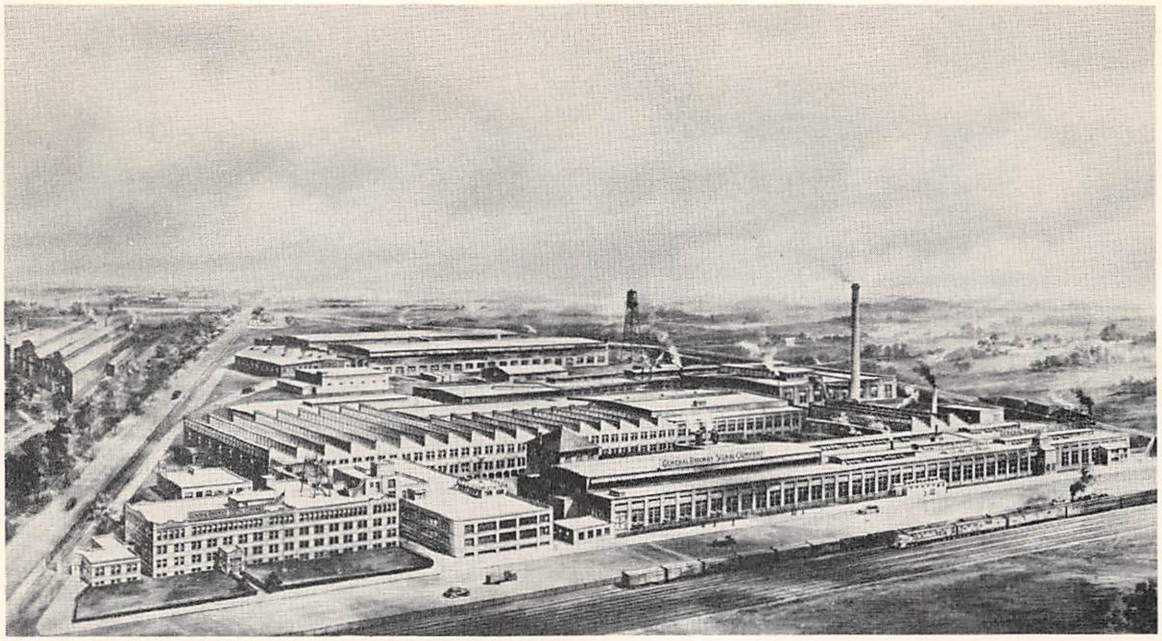
Both relays flash the signal lamps at a uniform rate regardless of ordinary variations in voltage or temperature. They each have four front and back dependent platinum-silver contacts which can carry a non-inductive tungsten lamp load of 5 amperes a.c. or d.c. at 30 volts or less. Unless otherwise specified, relays are adjusted to flash 40 to 45 times per minute.

G.R.S supplies a complete line of crossing protection equipment and can furnish circuits and devices arranged to meet a wide variety of requirements.

FOR MORE INFORMATION

about any of the systems described in this publication we suggest you communicate with your nearest G-R-S representative.

Should you be seeking information on any phase of railway signaling, technical data, economic studies, or consultation service, your G-R-S representative is ready to help you.



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